PREHISTORIC TOOLSTONE PROCUREMENT AND LAND USE IN THE TANGLE LAKES REGION, CENTRAL ALASKA

By

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Abstract

This project explores prehistoric human mobility and landscape use in the Tangle Lakes region, central Alaska through analyses of toolstone procurement and manufacture conditioned by site function. Early Holocene Denali and middle Holocene Northern Archaic traditions are hypothesized to have different tool typologies, subsistence economies, and land use strategies. However, few large, systematic studies of toolstone procurement and use have been conducted. At a methodological level, archaeologists have struggled to quantitatively source non-igneous cryptocrystalline toolstone which often makes up the largest proportion of archaeological lithic assemblages. These problems were addressed by developing rigorous chemical methods for statistically assigning lithic from Tangle Lakes assemblages to (a) two known local toolstone quarries, (b) materials within the Tangle Lakes region, and (c) non-local materials. Lithic technological and geospatial analyses were used to evaluate toolstone procurement, manufacture, and use within sites. Lithic samples from four archaeological components located at different distances from their nearest known quarry sources were used to address the research problems. The archaeological samples were derived from a Denali complex hunting site (Whitmore Ridge Component 1) and three Northern Archaic assemblages: a residential site (XMH-35), a tool production site (Landmark Gap Trail) and a hunting camp (Whitmore Ridge Component 2). Chemical results indicate that cryptocrystalline material in Tangle Lakes assemblages can be statistically assigned to primary sources locations, and visual sourcing of this material is entirely unreliable. Lithic analytical results indicate that despite slight changes in mobility strategies for Denali and Northern Archaic populations, site function is the strongest conditioning factor for material selection and procurement strategies local to the Tangle Lakes region. Thus, this research provides (a) best practice methods for sourcing abundance cryptocrystalline material that has been precluded from most lithic sourcing studies, and (b) the data necessary to incorporate technological organization strategies of Tangle Lakes populations into the broader context of Denali and Northern Archaic behavioral patterns in Alaska.

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Chapter 1: Introduction

1.1 Introduction

Over the years archaeologists have attempted to understand prehistoric toolstone procurement, human mobility, and landscape use without knowing the origin of the majority of materials that are part of stone artifact (lithic) assemblages (Coffman and Rasic 2015; Malyk-Selivanova et al. 1998; Phillips and Speakman 2009). Quantitative chemical analysis of toolstone material is the most reliable and consistent method for identifying sources of toolstone for material in lithic assemblages (Glascock et al. 1998). However, quantitative chemical sourcing of non-igneous material has been problematic due to variation in chemical concentrations of undifferentiable non-igneous cryptocrystalline toolstone artifacts and difficulty in locating these distinct sources on the landscape (Malyk-Selivanova et al. 1998). Non-igneous cryptocrystalline material, or common toolstone, often makes up a large majority of lithic assemblages globally (Selivanova et al. 1998). Therefore, quantitative source identification of common toolstone material in archaeological assemblages can provide high quality data to interpret material selection, transport, and use, especially in areas that lack detailed understanding of prehistoric procurement and mobility strategies.

The Tangle Lakes Archaeological District (TLAD) south of the Alaska Range in central, Alaska is a region of archaeological significance that has over 900 archaeological sites consisting mainly of common toolstone lithic assemblages (Figure 1.1). Further, the region was occupied after deglaciation approximately 12,000 cal yr B.P. by Denali Complex populations. Denali populations occupied the area from around 12,000 – 6,000 cal yr B.P., and subsequently, Northern Archaic populations occupied the region from approximately 6,000 – 1,000 cal yr B.P. Alaskan archaeologists are interested in reconstructing the behavioral patterns of these prehistoric populations in the sub-arctic because this information is relevant for learning how people managed mobility and subsistence systems in newly deglaciated and changing environments. Denali and Northern Archaic tradition procurement, mobility, and land use strategies local to the Tangle Lakes have not been systematically studied and identified because, prior to this research, the accurate sources of the common toolstone material in most of the lithic assemblages in this area were unknown.

Quantitative toolstone source identification can provide the spatial origin for lithics in archaeological assemblages. Subsequently, attributes of lithic debris represent human manufacturing practices and can be examined in association with toolstone material distribution to understand prehistoric procurement patterns and mobility.

The Tangle Lakes region is an optimal area for addressing the methodological research problem of sourcing common toolstone material because it contains two well-known prehistoric toolstone quarries (Landmark Gap and Long Tangle Lake Quarries) and several sites with lithic debitage assemblages directly associated with Denali and Northern Archaic occupations (Landmark Gap Trail, Whitmore Ridge, XMH-35) (Figure 1.1). These two quarries have never been characterized chemically, though many archaeologists have referenced toolstone material found in sites in interior Alaska as originating from these Tangle Lakes quarries. This research characterizes the material found at these two quarries to provide source origin data for lithics recovered from four archaeological components at three sites located within the Tangle Lakes Archaeological District. Ultimately, addressing the methodological problem of common toolstone sourcing in this study region can provide the information necessary to address the anthropological problem of reconstructing Tangle Lakes populations' mobility and land use strategies, so they may be incorporated into the broader context of Denali and Northern Archaic behavioral patterns in all of Alaska.

The project addresses two main problems in archaeological research. The first is that the ability to quantitatively source artifacts made of common toolstone has been problematic, which means sources of these material are not well understood in Alaska, and most parts of the world, even though they make up the majority of many lithic assemblages. The second problem is the need for identification of local toolstone procurement and land use strategies associated with the Denali and Northern Archaic populations in the Tangle Lakes region. The two research problems are related in that the first provides data to address the second.

Therefore, this thesis provides best-practice sourcing methods of common toolstone artifacts and the data necessary to incorporate the Tangle Lakes populations into the broader context of Denali and Northern Archaic behavioral patterns, in Alaska.

In order to address the first problem, the following questions were posed:

- What is the geological definition of the bedrock at the two Tangle Lakes quarries?
- Are the two quarries distinguishable on a chemical level?

- Can artifacts be chemically assigned to the quarry signatures?

Lithic attributes and geographic source provenance of lithic samples taken from components dated to the Early and Mid-Holocene periods are used to answer the following questions about human behavior and address the second problem:

- What activities were performed at each site component?
- Is there differential treatment of raw materials evident in each component?
- How does the treatment of materials from the Tangle Lakes Quarry and the Landmark Gap Quarry compare to the treatment of other local and non-local materials in each component?
- Which procurement strategies were performed in each site component?
- Do mobility and procurement strategies differ over time from the Denali to Northern Archaic occupations?
- Does site type systematically influence procurement and mobility?
- How do the technological strategies employed at these sites fit into the broader context of the Early and Mid-Holocene human behaviors in central Alaska?

The methods used to address these problems and to provide evidence for answering the research questions include: destructive wavelength-dispersive x-ray fluorescence spectrometry (WD-XRF), non-destructive portable energy-dispersive x-ray fluorescence spectrometry (ED-pXRF), multivariate stepwise discriminant function analysis (DFA), and individual flake attribute analysis (IFA). WD-XRF was used to analyze bedrock samples from the two Tangle Lakes quarries with the greatest analytical accuracy and precision to ensure high quality analysis for the quarries. ED-pXRF was used to analyze the quarry bedrock samples and the artifacts to make accurate artifact source assignments non-destructively. Multivariate DFA is used to calculate quarry signatures and artifact assignments. The artifact source information was used to evaluate behavioral models for toolstone selection and procurement. Four components were selected from three archaeological sites in the Tangle Lakes region for several reasons: (1) each component has large lithic debitage assemblages directly associated with a radiocarbon date associated with Denali or Northern Archaic occupation of the study region, (2) each site has a different function, and (3) each site is located at a different distance from each of the two prehistoric quarries. IFA on lithic samples taken from assemblages assigned to Components 1 and 2 at the Whitmore Ridge site, the Landmark Gap Trail site, and XMH-35, was used in conjunction with source information and site type to understand the relationship between nodule reduction, tool production, and material selection. Ultimately, this information was used to answer the questions above.

Multiple independent lines of evidence were incorporated into models that test expectations for interpretation of human behavior based on the distribution of lithic raw materials. Behavioral models are capable of distinguishing prehistoric raw material procurement strategies and selection by testing the distribution of raw materials based on expected conditioning factors of human decision-making. These condition factors are incorporated into models based on assumptions stemming from the Technological Organization theoretical framework. Proponents of the Technological Organization theoretical framework suggest that patterns of human behavior are identifiable at each stage of lithic material procurement, tool production, tool use, and discard.

Five models were developed to independently test expectations for procurement strategies and material selection based on proportions of different raw material types in each lithic debitage assemblage distributed from known and estimated raw material source locations. Expectations for raw material distribution in the site components were based on location of sources, cost of obtaining the materials, quarry attractiveness, material availability, and material diversity and evenness in the assemblages. The five models that were evaluated by applying these conditioning factors and associated expectations to the lithic assemblages include (1) a distance-decay model, (2) a cost distance-decay model, (3) a gravity-attractiveness model, (4) a Quarry Abundance Ratio (QAR), and (5) raw material diversity and evenness measures.

Overall site-type and activities that took place at each site may influence procurement strategies (Binford 1980; Roth 1998); therefore, prior to understanding raw material selection and use within each site, the site activities must be understood. Site-type was first established based on previous site literature and site activities were independently tested by lithic debitage attribute patterns within each component. The same lithic attributes in each component were evaluated in terms of raw material type, providing an additional line of evidence for explaining raw material selection, procurement, and use. Ultimately, the overall understanding of material procurement and activities at each site illuminates land-use in the Tangle Lakes during the Denali and the Northern Archaic Periods.

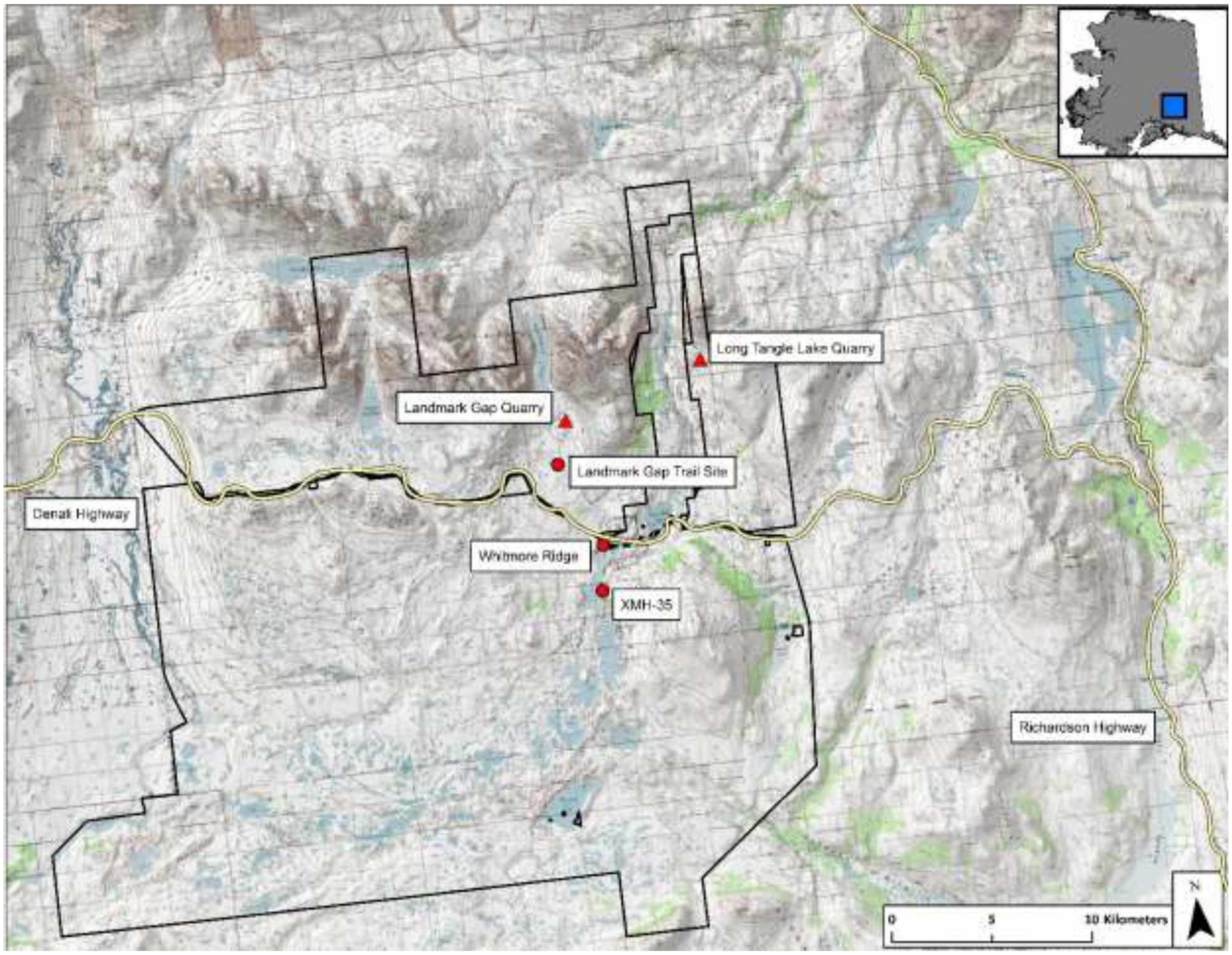

Figure 1.1 Location of the Tangle Lakes Archaeological District (TLAD) Study Area Boundary. The study area includes two known prehistoric quarries which were sampled for this study (Landmark Gap and Long Tangle Lake Quarries), and the three archaeological sites were selected for analysis in this study (Landmark Gap Trail, Whitmore Ridge, and XMH-35).

Prior to this research, there had been no attempt to use geochemistry to make accurate source assignments of the Long Tangle Lake and Landmark Gap Quarry material. An overarching hypothesis directs the sourcing study of these two quarries. The hypothesis asserts that the two distinct chemical groups will represent bedrock materials obtained from Long Tangle Lake and Landmark Gap Quarry, and that most lithic debitage from the four site components will be assigned to materials identified from these two quarries.

Quantitatively sourced lithic debitage in the archaeological assemblages represent independent lines of evidence that can be used in combination with physical attributes on the lithic debitage, conditioned by site function to address questions about procurement and mobility strategies, and land use.

Behavioral models predict prehistoric material selection and procurement based on expectations for the archaeological record built from assumed conditioning factors of prehistoric decision-making (Surovell 2009a, 2009b). Assumed conditioning factors are explicitly defined independently in the development of each model based on the Technological Organization theoretical framework (Nelson 1991; Surovell 2009a). Each model is tested independently; therefore, all else being equal, if patterns in the archaeological record adhere to expectations in the model, it is likely that the assumed conditioning factors incorporated into the model are important conditioning factors of human behavior (Surovell 2009a).

The distance and cost decay models have similar expectations because distance and cost of traveling between raw material sources and sites can be predictor variables, while the response variable is the amount of quarry toolstone in the lithic assemblages (Aubry et al. 2016; Beck 2008; Blumenschine et al. 2008; Michell and Shackley 2001; Ozbun 1991; Taliaferro et al. 2010). With regard to the distribution of raw material at the three sites, it is hypothesized that sites that are located closer or are less costly to travel to in relation to one of the sources will have more material from that quarry than the other (Beck 2008; Michell and Shackley 2001; Taliaferro et al. 2010). In addition, it is expected that sites located closer to a specific source will have lower diversity of materials; whereas, sites farther from the sources will have greater parity in source materials and greater diversity in source materials as reflected by a smaller proportion of artifacts assigned to the two quarries (Clarkson 2008). If the sites meet these expectations, then distance or cost/site location exerted a great influence upon lithic procurement, suggesting a direct procurement strategy for obtaining the materials. If, however, quarry materials were obtained from a farther distance or at a higher cost, and sites show greater material diversity and evenness, then a procurement strategy where acquisition of toolstone materials is embedded in other subsistence practices (embedded procurement) was likely employed to obtain materials (Brown 1991; Clarkson 2008).

Similarly, proponents of the attractiveness model maintain that “attractiveness” serves as a predictor variable influencing the proportion of material in each site as the response variable. An “attractiveness” value is calculated for each site relative to each source, taking into account physical traits of each quarry's material such as nodule size, difficulty of extraction, amount, and aspects of transporting the material from the quarries, such as terrain difficulty (Wilson 2007b). Therefore, it is expected that quarries with higher attractiveness values according to each site will have a higher proportion in each site. This model is operates under the assumption that prehistoric people will act rationally to maximize efficiency in lithic resource procurement but if expectations are not met it suggests that the factors incorporated into the model have less influence on the procurement of materials than other unknown factors (Wilson 2007b). If the sites meet the expectations, then it is likely that geographic and geological factors at each quarry have influences on material preference and procurement strategies will reflect the decisions to obtain the preferred materials (Wilson 2007b).

Finally, the Quarry Abundance Ratio (QAR), adapted from Soto and others (2017) Chert Abundance Ratio (CAR), and is based on the calculation of the amount of quarry material available on the landscape and predicts the amount of the two quarry materials at each site. The model is free of any assumptions associated with humans acting rationally to obtain material most efficiently, but rather based on people obtaining material that is physically available on the landscape. It is expected that if the ratios of quarry materials in the sites are similar to the QAR then a neutral material procurement strategy was likely employed (Soto et al. 2017). Alternatively, if the ratios of quarry materials in the sites are dissimilar then a selectionist procurement strategy was likely employed (Soto et al. 2017).

Lithic debitage attribute analysis is expected show patterns that reflect activities associated with each site type (Ferris 2015). The Landmark Gap Trail site has been called a lithic production site and a hunting overlook/scouting site (Gillispie 1992; Mobley 1982). The Whitmore Ridge site has multiple occupations and is considered a seasonal hunting camp through time (West et al. 1996). XMH-35 is a residential site with an identifiable hearth feature and house-feature depression (Robinson 2003). Therefore, it is expected that Landmark Gap Trail site debitage assemblage will reflect early stages of nodule reduction and tool production. There is no particular distinction in site type between the Denali and Northern Archaic components at the Whitmore Ridge site; therefore, it is suggested that the debitage should reflect all stages of lithic reduction and tool production with indications of formalized tool production based on respective Northern Archaic and Denali forms. Finally, it is hypothesized that XMH-35 will reflect a large number of activities represented by the highest proportion of late stage tool production and maintenance, as well as all stages of lithic reduction. These expectations exist because of the three site types that are discussed, the residential site was likely occupied the longest in a seasonal round, had the largest and most diverse population, and a variety of activities were performed.

The lithic attributes in terms of material type is highlighted in site type evaluation of raw material distribution. Site function is evaluated as the predictor variable and material type use will act as response variables. The site type hypothesis is that, differences in toolstone use are conditioned by site function. Specifically, it is expected that Landmark Gap Trail site will have the least toolstone diversity and greatest evenness because it is an initial tool production site. Further, it is expected that the majority of Landmark Gap Trail site debitage will be associated with the Landmark Gap Quarry and will represent manufacturing techniques for biface production. Due to the site's specialization in tool production, site occupants' main objective would have been to acquire material; therefore, it is likely that the material was procured from Landmark Gap Quarry directly for production of tools. The Whitmore Ridge site is expected to have slightly more toolstone diversity than Landmark Gap Quarry based on the interpretation that multiple activities occurred at the site. For instance, a hunting camp would include subsistence acquisition and butchery, potentially requiring different materials for different tasks and more opportunity to acquire toolstone from a variety of sources while procuring game (embedded procurement). XMH-35 is expected to have the greatest toolstone diversity and evenness. This is most likely if it was maintained as a residential site in which multiple activities occurred over a longer term of occupation. If no material was preferred for specific activities, it is likely that a variety of materials will be represented for a myriad of purposes at the site.

The change in quarry toolstone, local, and non-local material use is evaluated over time through a comparison of trends between Denali component and Northern Archaic components. It is expected that the site function throughout the two components and the distance to the source will be stronger actors on the distribution of toolstone at these sites than archaeologically-based cultural horizons. Therefore, it is expected that there will be comparable amounts of quarry material between the two Whitmore Ridge components, representing similar richness and evenness.

Finally, this research provides the data necessary to understand land use strategies through time, so Tangle Lakes populations' procurement, mobility, and land use strategies are incorporated into behavioral patterns of Denali and Northern Archaic populations in all of sub-arctic, Alaska.

1.2 Thesis Organization

Following the introduction in Chapter One, Chapter Two begins by outlining the archaeological theories applied to the data in an effort to answer the research questions introduced in Chapter One. The research design is outlined, including the research questions that drive the project, hypotheses, and expectations. Chapter Three provides a discussion of the Tangle Lakes region, including an overview of the study area, the geology, physiography, modern environment, paleoenvironment, regional stratigraphy, cultural background, and site distribution. The final sections in Chapter Three provide a detailed background of the sites selected for this study and how the lithic assemblages from each component were sampled. Chapter Four describes the analytical methods and materials used in the project. Specifically, Chapter Four provides a discussion of the chemical procedures used to produce the artifact sourcing evidence. Chapter four then outlines the sampling and analytical procedures to derive artifactual data used in conjunction with the sourcing data to understand procurement strategies. Chapter Five presents the results of the chemical quarry analysis, chemical artifact sourcing, and lithic analysis. Chapter Six presents a synthesis of the results of multiple behavioral models, and combines interpretations to understand Tangle Lakes land use patterns through time. Chapter Seven provides informed answers to the original research questions, explains the significance of the project, and offers suggestions for future research.

Chapter 2: Research Design and Theoretical Background

2.1 Introduction to Research Design and Theory

The aim of this research is to gain an understanding of prehistoric human lifeways through the analysis of lithic technology. Technological organization provides a theoretical framework to connect archaeological, ethnographic, ecological, geographic, and geological data to make inferences about past human behavior, focusing on why lithic technology is organized in a particular way in a given context (Carr 2005; Kelly 1988; MacDonald 2009; Nelson 1991). It is best applied to local environments and geographic contexts because technology is shaped by lithic resource availability, settlement patterns, and other aspects of a population and the area it occupies (Bamforth 1986). This research relies on toolstone sourcing, debitage analysis, and spatial analysis to understand toolstone procurement and human mobility. Primarily, this is accomplished by collecting chemical signatures of bedrock to define types of prehistoric toolstone. This information allows archaeologists to pinpoint the location of toolstone sources. Subsequently, chemical data collected from artifacts provide information about where artifacts originated. Qualitative and quantitative attributes are recorded through Individual Flake Attribute analysis (IFA) by recording metric and physical features that represent human modifications on each lithic debitage (Andrefksy 2005, 2007) a Modified Sullivan and Rozen Typology (MSRT) flake completeness in terms of flake size (Prentiss 2001), both in contrast to other methods, such as using a Mass Aggregate Analysis (Ahler 1989; Andrefsky 2007; Bradbury and Carr 2009; Bradbury and Franklin 2000). These methods for debitage analysis provide information about how humans designed and produced tools based on raw material abundance and structural constraints that are intrinsic to past hunter-gatherer foraging practices (Andrefsky 2009).

Debitage analysis provides a large dataset for recognizing patterns in lithic technology that are a result of repeated human behavior and patterns that can be connected theoretically to concepts of human behavior (Beck 2008; Carr and Bradbury 2001). The development of approaches for understanding the causes of variability in lithic assemblages led archaeologists to recognize the capabilities of lithic data, particularly lithic debitage, for evaluating human behavior. Debitage analysis has been shown to address problems related to source provenance studies (Eerkens et al. 2007), toolstone procurement (Brown 1991; Graf and Goebel 2009; Gramly 1978), tool production behavior (Ferris 2015), hunter-gatherer decision-making (Beck 2008), and risk management (Bousman 2005). In most cases, debitage analysis provides a larger sample for confirming behavioral patterns, as opposed to drawing inferences from a small number of formal tools, that often are biased by functional assumptions and multiple sources of variation (Beck 2008; Carr and Bradbury 2001; Sullivan and Rozen 1985). For instance, the pattern of a lithic debitage assemblage based off of its chemical signature, knowledge of discard based on site documentation and deposition provenience, and knowledge about manufacture/reduction strategies of unmodified flakes allows for the interpretations of how and why a material was, or materials were, transported across the landscape (Beck 2008). Behavioral interpretation is built on several lines of evidence connected with theories on Technological Organization, which describes patterns related to lithic technology in terms of economic and social decision-making.

Contrasting concepts often used to explain patterns in lithic technology include: collector verses forager, logistical verses residential mobility, curated verses expedient technology, and embedded verses direct procurement (Binford 1979, 1980). These dichotomous definitions may be overly simplistic for describing the complexity of human behavior; however, they do increase the understanding of possible causes of variability in lithic assemblages (Seeman 1994). These theoretical behavioral concepts will be referred to throughout this thesis and will be defined in the subsequent section prior to presentation of research design. The following section will elaborate on and describe the complex relationship between these concepts, as well as such factors that further complicate archaeological interpretation, as timing, risk-management, landscape familiarity, and toolstone preference.

2.2 Technological Organization and Behavioral Concepts

Technological Organization can be defined as “the study of selection and integration of strategies for making, using, transporting, and discarding tools and materials needed for their manufacture and maintenance” (Nelson 1991). It involves strategies that are a result of managing resource conditions and interaction with the environment (MacDonald 2009; Nelson 1991). As discussed in Nelson (1991), technological organization deals with all stages of a stone artifact’s life-history, from the procurement of the raw material, to the tool’s manufacture, use, and discard (Bamforth 2006; Bamforth and Bleed 1997).

While, some archaeologists continue to construct cultural-historical typologies (Magne and Matson 2008), compare reduction sequences (Sato and Tsutsumi 2007), and interpret cultural diffusion and replacement of lithic technology (Dibble 1991), others recognize that human behavior is represented at each stage of lithic production, use, and discard (Bamforth 2006). While it is important understand the cultural-history of a region in a general sense, such studies lack the ability to address human behavior. Stone artifact types are static if not evaluated along with the dynamic processes of activities associated with their formation, use, and discard (Bamforth 2006; Binford 1980). The study of technological organization increased the breadth of hypotheses and applicable archaeological, and environmental evidence to address human behavior by focusing on understanding why patterns in lithic assemblages are visible, why they are organized in a certain way, and how changes in technology reflect large-scale behavioral changes (Carr 2005; Kelly 1988).

Operationalization of models for subsistence and mobility strategies can be addressed by means of organizational principles of lithic technology. These organizational principles can be grouped into three components: stylistic, functional, and technical. These components when considered together will inform prehistoric human decision-making (Wiant and Hassan 1984). The *technical component* will be the focus of this research. Waint and Hassan (1984) define the technical component as the stages of raw material procurement, tool design, manufacture, use, rejuvenation, recycling, discard, and replacement. The evaluation of one or several of these stages is the general approach taken by archaeologists in their effort to elucidate patterns of prehistoric technological organization (Andrefksy 1994; Bamforth 1986; Bamforth and Bleed 1997; Brantingham et al. 2006; Garvey 2015; Goodale et al. 2008; Sassaman 1994; Shott 1986; Surovell 2003, 2009b; Tomka 2001). Wiant and Hassan (1984:105) assume that "technology is organized as an adaptive response to geographic and temporal variation in lithic and biotic resources and is designed to minimize tool costs." Thus, different patterns in aspects of the t*echnical component*, especially raw material procurement, allow archaeologists to make deductions about mobility strategies, settlement structure, and territory size.

Conditioning factors of technological organization that provide a basis for understanding prehistoric behavioral concepts were mainly conceived of by archaeologists through argumentation or ethnographic observation, and then tested against the ethnographic and archaeological record, in which case the concepts were reduced to measurable and testable models (Surovell 2003). However, due to the generalized nature of the concepts, the models suffer when assumptions and constraints are not explicitly stated (Surovell 2003). The concepts that warrant definition that will be referenced throughout the methodological discussion are logistic mobility, residential mobility, local verses non-local resources, curation and expediency. Some of these concepts have multiple definitions and uses but the following definitions will be used in the context of the present research.

Logistical mobility refers to the strategy of moving resources to people. A population lives at a residential base and subgroups go out on multiday trips to procure resources far from the residence and bring them back (Beck et al. 2002). Generally, it is assumed that the residential base is located near a single critical resource, but other necessary resources are far away (Binford 1980). This strategy is often associated with conditions that restrict the mobility of the entire group (Binford 1980). Residential mobility refers to moving the residence base to the resources. A population lives at a residential base which is the hub of subsistence activities because it is situated near an abundance of critical resources that people can collect on day trips (Binford 1980). When the resources around the residential base are depleted the entire residence moves (Beck et al. 2002). Varying degrees of residential and logistical mobility are possible and may shift based on seasonal changes in resource availability (Smith and Harvey 2018). Logistical and residential mobility are not dichotomous mobility systems, but rather practiced on a spectrum. For instance, populations could practice both high residential mobility and high logistical mobility as hypothesized for Denali Complex populations in Alaska during the Late Pleistocene and Early Holocene (Potter 2008b). The distances that prehistoric people were traveling and moving habitations and pursuing and moving resources are useful to archaeologists for determining prehistoric mobility strategies. Archaeologists often categorize evidence of human behavior to develop testable hypotheses. Exact extents of seasonal prehistoric human population movement in Alaska is difficult to define in Alaska, so defining a local verses non-local study region is useful when addressing the research questions in the Tangle Lakes.

The terms local and non-local/exotic are often used in discussions of prehistoric human mobility and resource procurement (Amick 1994; Andrefsky 1994; Beck and Jones 1990; Bever 2000; Blumenschine et al. 2008; Brown 1991; Camilli 1988; Carr 1994, 2005; Dibble 1991; Féblot-Augustins 2009; Goebel 2011; Graf and Goebel 2009; Jones et al. 2003; Kuhn 2004; MacDonald 2009). Often in research, local and non-local are undefined and therefore, not truly measurable. MacDonald (2008) defines local as lithic raw materials that occur in bedrock or secondary deposits at most 5-15 miles from an archaeological site. Alternatively, MacDonald (2008) defines semi-local to non-local raw materials occurring 30 miles or more from an archaeological site. Clarkson (2008) defines local as raw materials within 10 km of a site, and exotic/non-local materials at a distance greater than 10 km. Gould (1978:826) refers to “localized quarry sites in the vicinity of Puntujarpa,” are quarries the farthest, 32 km away from the site. Surovell (2003) and Smith (2011) add an interpretation of local verses non-local, defining local as ‘within a day’s walk.’ At the rate of 8 hours of walking at 5 km/h a day’s walk is estimated to be 40 km/day round trip (Smith 2011; Surovell 2003). Differently, Kuhn (2004) defines local and non-local based on the context of how raw materials were being used, thus raw material that is represented by a variety of products and lithic debris are considered local materials. Kuhn (2004) takes this approach to defining local verses non-local due to the contextual difference in scale of mobility of different hunter-gatherer groups, where in some cases traveling beyond a day’s walk from a site is “non-local” and other groups it is routine to transport materials over several hundreds of kilometers. Taking this perspective local and non-local could reasonably vary based on landscape barriers within certain areas. For this research local will be defined as within the boundaries of the Tangle Lakes Archaeological District, 226,660 square km (354.16 square miles). Non-local is outside of the boundary of the archaeological district. This boundary was chosen to define local resources because: 1) a trip from any given site within the boundary is approximately less than 18 miles (~29 km). This distance, slightly farther than a ‘day’s walk’ can also account for ability to travel farther from a residence based on logistical forays in a collector system (Smith 2011). 2) The archaeological district is resource rich and has a very dense distribution of sites. 3) There are natural physiographic boundaries such as the Amphitheater Mountains to the north, and the Maclaren River to the west that further reinforce boundaries for a local environment. Behavioral concepts connect physical distribution of lithic material on the landscape to attributes associated with prehistoric tool production on artifacts, in order to develop expectations for why lithic assemblages are patterned in certain ways.

Curation is a behavioral concept, but there is no true consensus for its definition or application. It has been conceived in several different ways: as a concept linked to mobility through transport and anticipated use of a tool, a manner of efficient of tool use, duration of use and utility, and recycling (Binford 1973; Shott 1996). The degree to which these variables influence patterned material culture, how they will be manifested, and how to separate the results of one variable verse another is a methodological challenge. However, curation is used and discussed extensively in archaeological literature relating to lithic technological organization.

Understanding curation can be approached through different avenues, such that the environment and toolstone availability can elicit the expectation that artifacts will exhibit curation

(Andrefsky 2009; Bamforth 1986; Carr 1994; McAnany 1988), while the demonstration of curation in artifacts can also be indicative of certain types of mobility (Bousman 2005), technological and procurement strategies (Bousman 1993), toolstone preference (MacDonald 2009), or risk (Bousman 2005). Andrefsky (2009) describes the beginnings of the curation concept as linking lithic technology to mobility patterns, such that curated technology verses expedient technology was superposed over residentially mobile foragers (curated technology) and residentially sedentary collectors (expedient technology) (Andrefsky 2009). Curation could be measured by quantifying efficiency, where efficiency is represented by utility of the tool in relation to energy required for manufacture and maintenance (Bamforth 1986). In this case, expectations for curated technologies are that it will be formal and applicable to a variety of uses, while expedient technologies are used for one situation then discarded, thus expected to be simple and applicable only to the immediate task.

To bring clarity to the meaning of curation Andrefsky (2009:71) lists five attributes that make up curation as synthesized from Bamforth (1986), these include: "(1) production in advance of use; (2) implement designs for multiple uses; (3) transport of tools to multiple locations; (4) maintenance of tools; and (5) recycling of tools" and additionally complex tools/flaking patterns. These five factors are important to recall when mapping the curation concept in the archaeological record because most archaeologists determine curation occurred within a lithic assemblage and address why by utilizing a method for measuring one of the factors and potentially testing it against another factor, or external factors, that would be a reason for curation.

Curation and expediency are often considered as a continuum of tool design, along with maintainability, reliability, versatility, transportability, and flexibility (Bousman 2005; Bleed 1986; Nelson 1991). Several technological organization studies, especially involving the analysis of raw material procurement have built expectations from these definitions. For example, it is expected that if there is high local raw material availability, curated toolkits and degree of retouch should decrease, and expedient production of toolstone on the local materials should increase (MacDonald 2008). Similarly, Bousman's (2005) model of prehistoric human mobility assumes all things being equal that collectors are associated with curation and foragers are associated with expediency; while, useful for the application, the reductionist model does not take into account that there is not a simple direct correspondence between these variables when varying conditions of raw material availability and tool needs are considered (Carr 1994).

This research will refer to curation loosely as similar to the term's used by Andrefsky (2009) and McAnany (1988), in that it will be understood through qualities of lithic debitage. In this sense, curation and expediency are considered along a continuum. Therefore, if a toolstone is heavily curated it would be limited to smaller sized debitage characteristic of re-sharpening, re-tooling, and *longevity* of tool use-life (Hayden et al. 1996; Terry et al. 2009). If curation is defined as a protracted use-life of a tool, then curation (use-life) of a tool will vary based on systems practicing direct and embedded, and indirect lithic procurement such as trade (McAnany 1988). This characteristic of toolstone use can be quantified by comparing debitage size and amount between raw material groups, contrasting these results with known lithic toolstone availability (Terry et al. 2009).

Raw material procurement strategies are intertwined with the curation continuum, the scale of human mobility, and lithic resources that people came into contact local and non-local to a study region. Embedded procurement is derived from the idea that procurement of raw materials is embedded in basic subsistence schedules and does not accrue its own cost separate from that of the cost of procuring the resource itself (Binford 1979). Embedded procurement does not necessarily have to be embedded in a subsistence activity but can be embedded in a social activity (Binford 1979).

Expectations for embedded procurement include increased richness, such that there will be a greater diversity of materials present in an assemblage because of higher encounter rates with different sources, and increased evenness, such that no one single material type will dominate the assemblage (Clarkson 2008). Embedded procurement may be associated with highly mobile populations that may not have continuous access to a single raw material source. In this case the expected archaeological outcome is formal tool manufacture, reducing transport costs, and increasing reliance on few durable and versatile tools (Kuhn 1994; Prasciunas 2007).

In contrast to embedded procurement, direct procurement assumes that "parties go out for the expressed and excusive purpose of obtaining lithic raw materials. Under such an assumption it is reasoned that a minimal 'costs' strategy should obtain" (Binford 1979:260). This definition is important because it elucidates potential archaeological expectations based on a "cost" minimization assumption, which is also derived from the description in Gould (1978) of direct procurement, that the expectation is that with increased distance between the source and locations of use the amount of bulk (unusable) material that is transported should correspondingly decrease (Binford 1979).

General expectations for direct procurement in the sense that a specific trip is made for the sole purpose of collecting the material include: at sites near the quarry there will be less material richness/diversity and less evenness (Clarkson 2008). Therefore, most directly procured lithic assemblages are made of one type of material because only a few other materials could have been encountered and worked into the assemblage (Clarkson 2008). If the material that is directly procured is nearby (local) and easy to obtain there may be signs of wasteful use and initial stages of reduction could be carried out at the use site rather than the procurement site (Andrefsky 1994). If direct procurement was occurring at some distance, such that it was nonlocal, initial stages of reduction should be carried out at the procurement site to minimize transport costs of non-usable materials (Kuhn 1994), and more highly curated because replenishing the material would require long distance travel (McAnany 1988).

2.3 Hunter-Gatherer Mobility Strategies

The data that will be presented to answer the research questions are components of a greater interplay between tool manufacture and site activities, procurement and transport patterns, and overall seasonal subsistence structure and mobility strategies. It is not appropriate to discuss causal relationships between these patterns, but rather important to recognize that multiple lines of evidence add to an overall understanding of the relationship between these behavioral patterns. Archaeologists find these behavioral patterns significant through time as they offer explanation for human colonization and mapping onto landscapes. The following paragraphs offer theoretical connections between the technological, spatial, and behavioral components associated with mobility strategies. These theoretical connections will be used with the lines of evidence produced in this research to guide behavioral conclusions for the organization of technology and land-use through time in the Tangle Lakes.

Mobility strategies refer to the patterns of movement that prehistoric populations employed to gather lithic and subsistence resources, and maintain a viable population (Binford 1980; MacDonald 1999). Patterns of movement are visible in ethnohistoric accounts of hunter-gatherers and prehistoric archaeological assemblages based on the materials discarded as a result of site occupation and movement (MacDonald 1999). Lithic and subsistence availability put constraints on human behavior and dictate how and when people chose to move to acquire the resources (Burke 2007; Ferris 2015; Goodale et al. 2008; Surovell 2009a). The constraints based on resource availability can be measured by archaeologists and modeled to predict prehistoric human mobility (Ferris 2015; Garvey 2015; Surovell 2009a).

Mobility and subsistence strategies, such as the continuum of logistical and residential mobility defined by Binford (1980), are often advanced in technological organization and lithic procurement studies (Bousman 2005). Archaeologists, such as Kelly (1988), make the argument that mobility is the main determining factor for technological organization and variability. Mobility strategies begin with the need for resource procurement which necessitates lithic raw material procurement. It is generally assumed that hunter-gatherers were always primarily concerned with subsistence resource procurement over stone procurement; however, the procurement of stone is critical to the acquisition of subsistence, especially game (Garvey 2015). The toolstone sources do not move but subsistence resources do; therefore, hunter-gatherers will always be adjusting their timing and planning of acquisition of subsistence, while managing and replacing toolstone based on how, where, and when they come into contact with raw material on the landscape (Amick 1994; Carr 1994; Kelly and Todd 1988).

Mobility strategies are used to infer site type and function because tool form and design are expected to vary with different strategies (Binford 1980; Nelson 1991). For instance, collectors are considered to have low residential mobility and high logistical mobility, whereas foragers are considered to have high residential mobility (Binford 1980). Different mobility strategies will alter hunter-gatherer's contact with lithic resources, such that mobility strategies actually change their lithic landscape (Montet-White 1991). Therefore, different mobility strategies will treat toolstone reduction differently. For example, high residential mobility assumes greater expediency in technological organization, while logistical mobility will benefit from a curated toolkit (Bousman 2005). In terms of raw material availability, expectations were that foragers would maintain highly curated tools of non-local material, but replace curated tools as needed by local materials, and use local material for expedient tools (Carr 1994). It is also expected that collectors "geared-up" with reliable tools of non-local material, but made expedient tools exclusively of local materials. Ultimately, time-stress and risk are constraints on human activity from the environment, but humans develop strategies for managing and adjusting time-stress and risk based on subsistence-settlement and mobility strategies (Elston and Brantingham 2002; Torrence 1983:14).

2.4 Lithic Procurement Strategies

Lithic procurement is a fundamental component of technological organization. It involves selection (Andrefsky 2005; Camilli 1988), acquisition (Bamforth 2006; Brown 1991), and management of the raw material used to manufacture stone tools (Goodale et al. 2008; Kuhn 2004). Physical features of the raw material (quality, size, form), and the strategies for raw material procurement will inevitably condition attributes of the other stages of technological organization (manufacture, use, and discard), which will form patterns of human behavior in the archaeological record (Adams and MacDonald 2015; Andrefsky 2009).

Understanding the effects of raw material procurement strategies on the archaeological record requires the development of concepts that relate the distribution of stone artifacts, the form, and potentially inferred function of artifacts to patterned human behavior (Aubry et al. 2016). Physical, economic, and social constraints can be delimited for prehistoric sources to reduce the number of human responses and decisions involved in acquiring toolstone to a manageable and testable levels (Aubry et al. 2016; Soto et al. 2017; Wilson 2007b). In understanding constraints on humans for procuring toolstone, there are often underlying assumptions of economic rationalism in evaluation of the costs (energetic/time/some not explicitly stated) associated with procurement (Aubry et al 2016; Taliaferro et al. 2010; Ugan et al. 2003).

Other archaeologists later argued that toolstone procurement costs are derived from a myriad of variables, such as time spent obtaining and processing material, transport costs, including weight and terrain difficulty, and scheduling costs between acquiring and processing stone verses encountering prey (Bousman 1993; Brantingham 2003). It is likely that procurement strategies are largely foraging system specific (contextual) because subsistence priorities might be different for different groups, and in different regions procurement could change based on changes in territory size, or seasonal distribution and availability of raw material in relation to food resources (Seeman 1994). In addition, there are a number of technical options at the procurement level of technological organization that determine the optimum strategy for a given socio-environmental hunter-gatherer context (Bamforth and Bleed 1997).

Procurement strategies may change based on seasonal availability of faunal resources and the association of these foraging territories with raw material resources (Beck and Jones 1990), and toolstone procurement accessibility in terms of other subsistence needs (Roth 1998; Wiant and Hassan

1984). The anticipated need of the tool is also expected to have an effect on how and what material is procured and the treatment of the material when it is procured (Hofman 1991), which may be attributed to planning depth. All of these factors are represented in the archaeological record. To understand the complex nature of lithic and resource availability, procurement, planning depth, timing, and mobility, additional expectations are based on known constraining factors. For instance, a set of expectations for strategies of lithic procurement are dependent on constraints due to the environment, such as toolstone availability, abundance, and quality (Andrefsky 1994; Larson 1994; Wilson 2007b). Specifically, the procurement strategies will vary based on constraints such as the geographic distribution, size and nature of the source, the quality and form of the nodules, and if, and how, the raw material is exposed on the landscape (Roth 1998). This accounts for variation based on the geomorphic characteristics of the bedrock at the procurement site. These variables inform the decision-making and selection of toolstone (Bettinger et al. 2015). Several models built from raw material availability will be tested with the Tangle Lakes dataset to understand material selection and procurement strategies.

Procurement of materials may also be conditioned by colonization of new and unfamiliar territories, as seen archaeologically through evidence of material conservation because in these situations hunter-gathers run the risk of not knowing the next available raw material source but still need to be prepared when encountering food resources (Hiscock 2002). This scenario may be considered for the Denali Period component of Whitmore Ridge, one of the earliest dated components in the Tangle Lakes. This treatment of material will be different from locations where raw material is well-known and abundant, and populations are more sedentary, such that wasteful, expedient technology is expected (Thacker 1996).

2.5 Identifying Procurement and Mobility Strategies from Archaeological Patterns

Lithic technology is a reductive system, due to the nature of producing tools by reducing stone nodules. Therefore, lithic debitage should follow the law of monotonic decrement from source to discard, which is a consistent pattern with which to assess toolstone procurement in the archaeological record (Eerkens et al. 2007; Renfrew 1977). In the context of lithic distribution this law describes the following pattern: the average size and amount of debitage produced from a raw material nodule in the reduction process will decrease as the distance from the raw material source increases (Eerkens et al. 2007; Renfrew 1977; Sidrys 1977).

This pattern on a general scale is well tested; it has been shown that as the distance increases from a known quarry the amount of the particular quarry's material decreases and is replaced by a variety of other materials (Mitchell and Shackley 1995; Ozbun 1991). The distance-decay concept is also used to determine how far away raw material sources (procurement sites) may be from a site based on the distribution of varying amounts of particular raw materials in site assemblages in a study area (Blumenschine et al. 2008; Coffman and Rasic 2015). Though the distance-decay pattern is usually applicable on a broad scale, the model is rather simplistic and cannot explain all of the variability in archaeological assemblages. For instance, energy efficiency optimization is often an implicit assumption in the distance-decay models. While, other models apply optimization assumptions with the discussion of the cost of transporting material and potential for influence of "effective distance," which considers terrain difficulty rather than simply linear distance (Renfrew 1977). Concepts of cost as a function of raw material transport distance and terrain difficulty have been tested explicitly within optimization models (Wilson 2007a, b). Technological investment relates to subsistence because in order to gain energetic calories by hunting, expenditure of time and energy costs are required for stone tool procurement, production, transport, and use (Ricklis and Cox 1993). Therefore, technological investment can be analyzed using optimization models (Beck et al. 2002; Taliaferro et al. 2010). Terrain difficulty is not the only confounding factor of the distance-decay model, it has been argued that direction of movement and anticipated need of an artifact before reaching another quarry may change the pattern of lithic distribution (Hofman 1991). Additionally, the abundance (amount) of stone artifacts is not the only variable that is affected by distance to the raw material source. Assemblage variability, recognized by tool and toolkit design, and also by site formation may be influenced by distance to the raw material source (Wiant and Hassan 1984).

Several studies that evaluate lithic procurement as an optimization problem are more robust approaches to distributional distance-decay studies. For example, Wilson (2007b) formulated a *Gravity Model* which uses a mathematical equation to calculate attractiveness of a raw material source, which is attractiveness: *A(s) = (quality x extent of source x 100)/difficulty of terrain x cost of extraction) x size/scarcity*. All other factors being equal, raw materials with higher attractiveness values are expected to be preferred and selected over materials with lower attractiveness, and failure to meet these expectations is the result of subjective human factors (Adams and MacDonald 2015; Wilson 2007b). A similar model will be tested in this research using the Tangle Lakes dataset.

The research presented in this thesis attempts to control for a variety of the confounding factors to the most simplistic distance-decay model for raw material distribution by testing multiple models. These models include a test of expectations for Euclidean distance-decay, cost-distance-decay, a gravity-attractiveness model, and a Quarry Abundance Ratio based solely on expectations for proportions of materials that are available on the landscape.

However, assemblage material and lithic variability can also be caused by a number of other of other factors such as tool function, reuse, and scavenging (Beck 2008). Archaeologists reduce the amount of potential confounding factors causing assemblage variability by focusing on the procurement stage of the technical component of technological organization and by including an analysis site-type and site activities

The site type approach evaluates the link between technological organization and settlement models that have inferred site-types such as residences or camps based on Binford (1980) collector/logistical and forager/residential descriptions, or inferred activities such as a procurement/extraction site (Nelson 1991). Site-type procurement approaches evaluate the site structure based on a site's artifact assemblage with regards to raw material availability and distribution.

Operationalization of site-type approaches involve a determination of site type or function based on expectations of tool assemblages, such that curated technologies will be associated with logistical camps of collectors, while expedient technologies will be associated with seasonal, short-term residences of foragers (Bousman 2005). Similarly, it has been argued that formal/curated tools made in advance of anticipated use with high transportability will be associated with highly mobile logistical camps, whereas more sedentary tasks will be accomplished with expedient or informal tools that require little effort in preparation (Andrefsky 1994; Bleed 1986). Site type and mobility strategy can also be inferred using other archaeological information such as presence of other archaeological features, such as pit structures and storage features (Roth 1998) and site location (Jones et al. 2003; Smith 2011).

In site-type studies lithic assemblage materials are evaluated based on ratios of raw material types alone and raw material types associated with tool forms, debitage size, tool to debitage ratios, degree of retouch, stage of reduction, and use-wear or damage at a particular site type (Andrefsky 2008, Kozlowski 1991; Roth 1998; Sassaman 1994). These studies seek to understand how raw material availability may have constrained its use by prehistoric populations using certain mobility strategies, and how raw material quality will affect peoples' selection of material for specific tool manufacture (Andrefsky 1994; Roth 1998). Access to raw material of particular qualities has been shown to be associated with certain tool forms/designs (Kuhn 1995), which are often required for maintaining a given mobility strategy, such that formal tools must be transportable and reliable. There should be no risk in the tool failing when the subsistence resource is targeted, so collectors that relied on the function of formal tools would have been more selective about their raw material (Bousman 2005).

The above sections describe the connection between land-use, mobility, and technological organization, specifically at the level of raw material procurement. Then approaches for recognizing these patterns from the archaeological record are outlined. In the sections below, the methodological application of obtaining the lines of evidence used to test the behavioral expectations are discussed. This includes the appropriate application of quantities chemical toolstone sourcing, with which to connect artifacts provenienced in their location of discard with their materials' origins. It also includes lithic debitage attribute analysis to connect the spatial data with indicators of specific human activities.

2.6 Toolstone Sourcing and Goals of Chemical Analyses

Technological Organization and behavioral concepts need to be operationalized through models based on explicit expectations for how behavior will be represented in the archaeological record. Lithic procurement strategies and toolstone selection can be examined with knowledge of artifact origin in relation to point of discard. While it is possible to infer procurement and mobility strategies with the knowledge of debitage assemblage formation processes, and treatment of different toolstone types, adding evidence for the toolstone origin provides more robust knowledge of how the material was obtained. Therefore, conditioning factors for mobility strategies in a local context can be more explicitly understood. In this study, application of toolstone sourcing allows the development of models to determine, all else being equal, if Landmark Gap Quarry and Long Tangle Lake Quarry sources are the only two local quarries, the percentage of these toolstone materials expected in each site at varying distances from these quarries should accurately represent procurement strategies and material selection. However, prior to testing such a model, data must be produced to determine specific toolstone sources.

Chemical analysis has been applied to a number of archaeological materials, but this project relates to lithic artifact sourcing; therefore, the discussion of these questions will relate to their application to lithic assemblages and stone, with regards to determining the source of the artifacts' materials.

In Alaska archaeologists have focused research on chemically sourcing volcanic materials (Coffman and Rasic 2015; Cook 1995; Gore 2019; Reuther et al. 2011) Igneous artifacts lend themselves well to chemical analysis of trace elements because the rapid cooling of material during formation leads to toolstone that usually has a microscopic grain size, is smooth, and chemically homogeneous within a distinct outcrop (Andrefsky 2005). Therefore, without prior knowledge of volcanic source chemical signatures, chemical groupings resulting from chemical analysis of artifacts in assemblages likely represent true source groupings. However, volcanic materials only make up a small portion of most archaeological lithic assemblages because the majority of the "common toolstone" material is sedimentary or metamorphic. Therefore, the majority of lithic technology that can contribute to an understanding of prehistoric human toolstone procurement and mobility is not included in sourcing studies. Sedimentary toolstone material, such as chert, can be chemically heterogeneous, so much so that different locations on the same artifact will have very different chemical signatures. Attempts to use XRF to chemically distinguish similar chert types in a lithic assemblage and further match them to the source have had little success by analyzing chert samples (Nazaroff et al. 2013; Selivanova 1998), but usually conclude that qualitative petrological and thin section analysis is more informative (Fuertes-Prieto et al. 2016; Milne et al. 2011). On the other hand, fine-grained volcanic rocks, such as obsidian (Ericson and Glascock 2004; Jones et al. 2003; Reuther et al. 2011), rhyolite (Coffman and Rasic 2015; Dello-Russo 2004), and basalt (Johnson 2012; Lunbald et al. 2012) have distinct homogeneous signatures that are a result of rapidly cooling volcanic events that form outcrops which can be located on the landscape. If it is possible to chemically identify distinct elemental signatures for the Long Tangle Lake and the Landmark Gap Quarry materials, regardless of each material type it will be possible to identify these source groupings of artifacts in the archaeological assemblages. The ability to perform a sourcing study by chemically identifying source material prior to making artifact groupings is what makes sourcing non-igneous "common toolstone" possible.

A series of questions must be answered in order to carry out chemical sourcing in the context of this research properly. The first level of questioning is: How many different raw material sources (the origins of materials) are present in the assemblage? The sample for chemical analysis of artifacts must encompass all the predicted variability in a material that could be attributed to a source or multiple sources, thus the larger the sample the more representative of chemical variation there should be (Shackley 2005). There has been debate/concern about the overall understanding of what it truly means to apply compositional data to determine the "source" of an artifact (Frahm 2012; Neff 1998). Neff (1998) reminds archaeologists that the multidimensional compositional concentration units obtained by chemical analysis must be reliably and validly assigned to geographic coordinates to determine a "source;" the compositional units themselves are not oriented in space. In a more extreme sense, it is argued that nothing is 'truly' sourced, rather stone sourcing is a statistical probability and only varying degrees of probability can be achieved for determining the actual source of material on the landscape (Pitblado et al. 2008; Shackley 1998). Furthermore, simply determining the source of a material does not address human behavior, because the only information provided from "sourcing" is the "measure of physical displacement of materials" (Hughes 1998). These data points (compositional groups of artifacts assigned to a source, and source location) must be evaluated in conjunction with additional lines of archaeological evidence and theory to discuss material procurement (Beck et al. 2002), mobility (Jones et al. 2003, 2012), exchange (Ogburn 2011), and social interaction (Phillips and Speakman 2009; Smith et al. 2007).

Once the chemical signature of the source material is statistically correlated to the artifacts' chemical signatures, then the geographic location of the source has a high probability of being the location that humans initially acquired the material. This therefore is used to answer the second 'level' question: Where did the material that humans were using to manufacture artifacts originate (Fuertes-Prieto et al. 2016; Pitblado et al. 2008)? The third level question that can be addressed using the provenance information is: What anthropological mechanisms were employed to displace the artifacts from the original source to the place of discard (Jones et al. 2003; Sheppard et al. 2010; Smith 2010)?

This project does not approach the questions in the exact order listed above due to the unique context of the dataset. Since the locations of the lithic material sources were already known in the study region but the material type and the extent to which these quarries were utilized prehistorically was not known, the research questions took the following trajectory: What is the geologic definition of the material at each quarry? What elements best demonstrate intra-quarry homogeneity and inter-quarry heterogeneity? How many artifacts in the lithic assemblage samples are from these two local quarries? What procurement strategies and mobility patterns can be identified based on the distribution of lithic technology from these two quarries, and how can it be understood in terms of the other local and non-local materials in the site assemblages?

In order to address these questions chemical analysis must be appropriately applied to the dataset theoretically and technically. The 'best practice' for chemical analysis of the dataset in this study included the use of WD-XRF on the bedrock quarry material, and ED-pXRF on both the bedrock quarry material and the artifacts. The following sections will discuss the theoretical and technical aspects of these analytical techniques to provide background for the methods used in this study.

2.7 Research Questions and Operationalization

Archaeologists are interested in reconstructing key aspects of prehistoric human lifeways, such as mobility strategies, subsistence patterns, and landscape use. In ideal cases, archaeologists can address how human lifeways shifted through time and changing environments. The Tangle Lakes region has an abundance of archaeological material culture that can be used to evaluate shifts in human mobility and landscape use through time. This project seeks to understand how prehistoric inhabitants of Tangle Lakes moved across the landscape interacting with known local toolstone sources and utilizing other unidentified local and non-local toolstone sources. Overall, mobility strategies and landscape-use will be evaluated through toolstone procurement, manufacture, and discard, based on expectations derived from the Technological Organization theoretical framework.

To answer the research questions concerning comparisons of lithic procurement and mobility during the Denali and Northern Archaic periods, the relationship between toolstone origin, lithic production, and discard must be evaluated. This is accomplished by identifying local and non-local materials and testing quantitative methods for toolstone source identification. Subsequently, data recorded from attributes of lithic debitage are evaluated in terms of raw material categories that are linked to source location. Debitage is targeted as the product of human behavior that is to be evaluated because it occurs in larger quantities and is not as susceptible to biases based on less predictable tool transport, thus providing a more robust sample from each site (Shott and Scott 1995).

The hypotheses and expectations for this project build off a foundation of rigorous chemical expectations. The overarching hypothesis relating to the chemical sourcing is that two distinct chemical groups will represent Long Tangle Lake Quarry and Landmark Gap Quarry, and most artifacts from the four site components will be assigned to each quarry grouping. The following hypotheses are a model for understanding human mobility based on the distribution and use of toolstone at sites that have multiple avenues for evaluating the lithic data.

Once the artifacts can be securely assigned to one of the two quarries, or neither quarry, hypotheses can be made relating to prehistoric human transport of the materials from the quarries. The following research questions and associated hypotheses and expectations are outlined in the subsequent paragraphs.

This project will answer these questions:

1) Is there differential treatment of the raw materials within each of the site components: Whitmore Ridge Components 1 (C1) and 2 (C2), Landmark Gap Trail Site, and XMH-35? The answer to this question is foundational for the following questions. It will be accomplished by employing IFA from criteria derived from Andrefsky (2005) and Modified Sullivan and Rozen Typology (Prentiss 2001), to record attributes on debitage samples of unmodified flakes from each site component. These attributes will be compared based on raw material type. Local is defined as within the Tangle Lakes Archaeological District boundaries. A proportion of each component is expected to be Landmark Gap Quarry and Long Lake Quarry toolstone, while the rest is likely a combination of other local and non-local materials. Debitage from local sources are expected to represent all stages of manufacture, especially larger and early-stage flaking debris, while debitage from non-local sources will be restricted to small tool-maintenance debris (Eerkens et al. 2007). Patterns of raw material conservation of the toolstone material with unknown sources will be compared to the treatment of the material with known sources and definitively non-local sources, such as obsidian. Conservation is considered the economic treatment of toolstone (Dibble 1991). Material conservation is associated with extending use-lives, and recycling tools (Hiscock 2009). This may be recognized in debitage analysis by the presence of rejuvenation, and retouch debitage (Andrefsky 2009), such as late stage reduction that is often characterized by greater than four dorsal scars, complex platforms, and small debitage sizes (Ferris 2015). After assigning chemically analyzed artifacts to either of the local quarries, attributes associated with material conservation will be used to categorize remaining artifacts with

unknown sources into estimated local and non-local materials. Then, the treatment of material from multiple estimated local and non-local sources is compared to treatment of the material from the known local sources (Landmark Gap Quarry and Long Lake Quarry). It is expected that non-local materials (obsidian artifacts serve as a standard for non-local material treatment) will exhibit indications of high material conservation. Within the local materials, it is expected that conservation will increase as distance of the site components increases from the quarry sites, such that flake size and amount will decrease, flakes will exhibit increases dorsal flake scarring, and complex platforms. A quantitative model may be developed to test expectations for the percentage of each known quarry material in each lithic assemblage at the three sites in this study, based on distance to the source and under the conditions if no other local resource were available (Adams and MacDonald 2015; Soto et al. 2017; Wilson 2007b).

2) How does the treatment of two local Tangle Lakes quarry toolstone materials (Long Tangle Lake Quarry and Landmark Gap Quarry) compare to other local and non-local materials being used by Early and Mid-Holocene populations? This question will be addressed using the same measures and expectations as the previous question, but rather than examining raw material and distance as the predictor variable, time will be the predictor variable.

3) What procurement strategies are present in all of the site components? This question will be addressed using the same lithic attribute measures in terms of raw material type, but expectations will be oriented to larger scale movements and how humans may have encounter additional materials. Expectations for embedded procurement include increased richness and evenness of materials present at the sites verses direct procurement in which case a decrease in richness and evenness is expected (Clarkson 2008). In instances of embedded procurement, in which material was picked up and used incidentally during subsistence activities and may also have been collected in anticipation of a return trip to a habitation, it is expected that debitage associated with embedded procurement should occur at habitations as primary flakes and shatter, and numerous cortical pieces (Brown 1991).

4) Are human mobility and toolstone procurement strategies different between the Denali and Northern Archaic periods? It is assumed that procurement costs could change if group mobility changes (Surovell 2009b), in which case identifying shifts in procurement strategies through time could indicate changes in mobility strategies through time. This will be addressed by identifying procurement strategies based on the lithic attributes of debitage associated with tool manufacture in terms of raw material type and the source of the material. This will be examined at the scale of local and non-local sources and the two known locations of local toolstone. Procurement strategies will be compared through time by investigating temporally comparable site components dating between the Early Holocene and Mid-Holocene. Whitmore Ridge Component 1 is the best dated Denali Complex – Early Holocene component, and therefore it will be compared to the Northern Archaic – Mid-Holocene component at Whitmore Ridge, Component 2. It is expected that the site function throughout the two components and the distance to the source will be stronger actors on the distribution of toolstone at the site, therefore there will be comparable amounts of quarry material between the two components, representing similar richness and evenness. Additionally, procurement strategy shifts will be evaluated with regards to temporally distinct available subsistence resources and landscape changes in the local context of Tangle Lakes.

5) Does site type (e.g. residential verses lithic workshop) influence procurement and mobility strategies between the Denali and Northern Archaic period consistently? Site type likely has an influence in how toolstone was procured and utilized in the Tangle Lakes region, understanding procurement strategies through time in the context of each site type will indicate if the site type was an influence on procurement strategy. The Landmark Gap Trail Site is a logistical stopping point/site that could be considered a primary reduction location and game lookout. It is expected that material was directly procured from the closest local source (Landmark Gap Quarry) and manufactured into tools or preforms at this site. Therefore, it is expected that the assemblage will display low raw material diversity, associated with material richness and evenness. Whitmore Ridge is interpreted as a seasonal hunting camp, occupants of the site are associated with high logistical mobility, as such, inhabitants may have encountered multiple toolstone sources. It is expected that this

site will have a high raw material diversity, but potential toolstone preference for curated technology for hunting reliability and maintainability. XMH-35 is a residential site with multiple occupations, based on ethnographic movements of groups it is likely the population of XMH-35 was more residentially mobile occupying the site in the resource rich Tangle Lakes area seasonally. It is expected that this site will have the highest toolstone diversity and evenness, demonstrating embedded procurement with expedient use of local materials and curation of non-local materials. Further, if the material from the two known quarries was not favored above other materials, it will be evenly distributed across different debitage types.

6) How does the technological organization and behavioral strategies correspond with the broader understanding of Early to Mid-Holocene archaeological patterns from previous research in the Tangle Lakes region and central Alaska? Answering this question will add to information from previous studies in central Alaska focused on prehistoric human behavior, seasonal subsistence strategies, and intrasite variation throughout the Holocene (Mulliken 2016; Potter 2005, 2007, 2008a, 2008b, 2008c; Glassburn 2015; Holloway 2016; Wendt 2013). Two chronological gaps are visible in the archaeological record in the Tangle Lakes, one between approximately 10,000 cal yr B.P. and 6,200 cal yr B.P., and a second between 4,000 cal yr B.P. and 3,000 cal yr B.P. (Potter 2008b). Increase in population around 6,200 cal yr B.P. in the Tangle Lakes and other upland regions in central, Alaska is correlated with the emergence of the Northern Archaic technological trend (Potter 2008b). Potter (2008b) hypothesized that increased population associated with a technological trend and increased representation of caribou remains in these archaeological components could be associated with a widespread change in land-use strategy between the Early and Mid-Holocene. The hypothesis that landscape use changed between these populations will be addressed in particular to the Tangle Lakes relative to these populations in the rest of Alaska. The Tangle Lakes focused study can provide valuable information on human behavior and mobility in an effort to develop more research questions at a broader scale and also place Tangle Lakes archaeological district into a dynamic context with the rest central Alaska.

This research adds to the understanding of Holocene human subsistence and mobility strategies in central Alaska by evaluating toolstone procurement and technological organization. The ability to source non-igneous – common toolstone material in Tangle Lakes archaeological assemblages in this study provides an avenue for high resolution evaluation of mobility strategies for each site component. Previous paleo-environmental research and site reports in Tangle Lakes provide environmental and subsistence data through time with which to add as lines of evidence to understand procurement and mobility strategies.

To operationalize this research design and test these hypotheses data were produced that encompass multiple lines of evidence in the Technological Organization framework. Spatial data of artifact origin and location of discard were produced using chemical sourcing techniques. Lithic attributes associated with human behavioral patterns were recorded through individual flake debitage analysis. Understanding the background and assumptions of these data production techniques is important to how they are applicable to the research design.

2.8 WD-XRF and ED-pXRF of Geological and Archaeological Samples

There are multiple types of X-ray fluorescence (XRF) spectrometers, which should not all be considered and treated equally. XRF spectrometers should be selected based on its appropriateness for answering a specific research question at a given scale, based on the context of the information that can be acquired. Further, different spectrometers, calibrations, and methods for application are also contingent on the properties of the artifacts that are being analyzed. Physical characteristics of the artifacts, such as surface weathering, thickness, size, and surface topography can have an effect on how to use the XRF device.

Differences in capabilities of XRF devices depend on whether the XRF spectrometer is wavelength-dispersive or energy-dispersive (Garrison 2016). Additional differences in capabilities are attributed to whether or not the devices use a destructive form of analysis (Williams-Thorpe et al. 1999), and finally if the device is a stationary lab XRF spectrometer or a handheld portable XRF spectrometer (Frahm 2014). Important differences to keep in mind are that of precision and accuracy of the measurement taken by the instruments; precision meaning the ability of a device with constant analytical conditions to take a series of measurements and get the same results each time, and accuracy meaning the closeness of a measurement to the true/actual value of the elemental concentration (Frahm 2012).

Both Wavelength-Dispersive XRF (WD-XRF) and portable Energy-Dispersive XRF (ED-XRF or ED-pXRF) spectrometers collect and read the wavelength of characteristic elements of a material when the material is bombarded with X-rays, which causes a displacement of electrons that produces a secondary (fluorescent) spectrum (Garrison 2016). There are several main differences between the two that result in differences in their accuracy and precision. WD-XRF initially irradiates a sample directly with an X-ray, the subsequent characteristic radiation from each element in the sample is diffracted through analytical crystals and separated into individual X-rays characteristic of each element based on its wavelength, which is then collected by the WD-XRF detector and converted into elemental energies (Garrison 2016; Panalytical 2018). The use of multiple crystals, separating x-ray photons by diffraction and individual x-ray tubes allows for high resolution of X-rays of specific wavelengths the WD-XRF, which results in better discrimination of all elements than an ED-XRF (Garrison 2016; Shackley 2012a). ED-XRF measurements are the result of the fluorescence of crystals (the scintillation detector) when hit by the secondary X-rays (Shackley 2012a). ED-XRF measures all the secondary X-rays from elements together on one detector using one channel; therefore elements cannot be selected individually, making this technique more susceptible to interelement interferences (Shackley 2012a). For instance, the ED-XRF is incapable of distinguishing Ti K-alpha radiation from Ba L-alpha radiation (Figure 2.1). This makes WD-XRF more quantitatively accurate than ED-XRF (Garrison 2016), and also more precise than ED-XRF because the energy is separated into individual channels (Shackley 2012a).

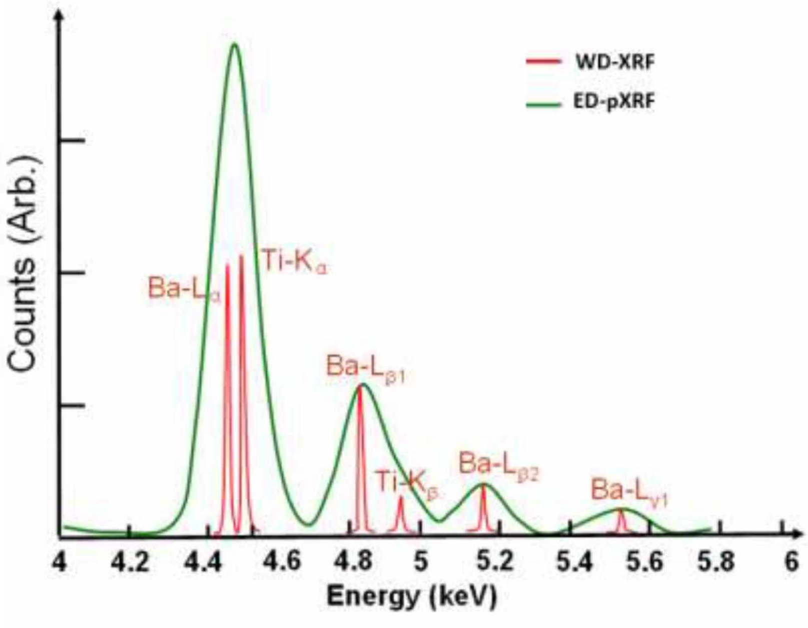

Figure 2.1 Characteristic radiation of BaTiO3 measured on a WD-XRF and an ED-pXRF. The graph is modified from Liao (2018), and demonstrates the inability to distinguish the Ti K-alpha radiation from Ba L-alpha radiation on the ED-pXRF to due to poor energy resolution.

WD-XRF has better sensitivity (measured by detection limits) than ED-XRF approaching the parts per million level; however, the general detection limit capability of ED-XRF is 0.5% to 0.05% (Garrison 2016). The detection limit varies because some elemental interferences are more common than others. Some of the x-rays for heavy elements will go through the ED-XRF detector crystal (Garrison 2016). If the archaeologists know the detection limits are great enough to account for the elements of interest, the difference in detection limits may not deter use of an ED-XRF. For instance, ED-XRF can have high accuracy, comparable to that of Neutron Activation Analysis for mid-Z and some high-Z elements, such as Rb, Sr, Y, Zr, Nb, and Ba depending on the concentrations of the samples and interfering elements ; therefore, it has been a clear choice for chemically analyzing obsidian (Shackley 2005). Precision of an instrument can be checked by running repeated measures of a sample to determine if the level precision that the devices is operating is acceptable (Shackley 2005). Accuracy of an instrument may be evaluated by repeated measurements of geological standards.

Despite ED-XRF having poorer precision and accuracy than WD-XRF, there are a number of instances that make it the preferred technique for archaeological analysis. The WD-XRF only measures one element at a time, making it a much more time consuming technique than ED-XRF (Shackley 2012a), additionally samples analyzed with a WD-XRF must be completely flat and homogeneous in grain size because it is important that the secondary x-rays hit the crystals at the appropriate angle, based on Braggs Law (De Francesco et al. 2012; Shackley 2012a). Due to the need of a flat surface, WD-XRF is usually destructive. ED-XRF is less susceptible to surface irregularities and is often performed completely non-destructively (Johnson 2012; Shackley 2012a).

Most concern with the treatment and effects of artifacts when applied to non-destructive ED-XRF studies is how to calibrate and operate the device correctly to obtain the appropriate results, and account for the effects of specimen size depending on method/device (Shackley 2012a), thickness (Ferguson 2012), surface irregularity effects, such as topography (Jones et al. 1997) and weathering patina or corrosion (Gauthier and Burke 2011; Mass and Matsen 2012), matrix effects, caused by composition, grainsize and minerology of the sample (De Vleeschouwer et al. 2011), and chemical variability in a sample (Donais and George 2012), mass absorption effects from fluorescence radiation being absorbed by coexisting elements (Shackley 2012b; Williams-Thorpe et al. 1999).

Tests of effects of sample thickness for the portable XRF analysis mid-Z elements show that element values are unaffected for sample with a thickness greater than 1.5 to 2.5mm and a diameter of 10mm (Davis et al. 2012). As long as the archaeologist uses a ED-XRF sample dimensions should not be a problem as long as it covers the beam aperture (Moholy-Nagy et al. 2013), however it is worthwhile if there is a larger sample to run an analysis on multiple spots on the sample to understand the chemical variability within the sample itself (Donais and George 2012). If a sample is not thick enough it is possible that the irradiation beam could go through the material being analyzed, but it is argued that calculations and orientation of the artifact can offset the issues with thickness (Frahm 2016). Though the reliability of results is disputed for samples that are less than 2mm thick (Shackley 2012a) and lack of infinite thickness could cause problems with Compton peak normalization (Ferguson 2012). Concerns about surface irregularities and weathering (Lunbald et al. 2012) can be offset using correction procedures (Williams-Thorpe et al. 1999). Samples that are not completely flat and these procedures can be successful for resolving airgaps up to 3mm (Potts et al. 1997). Matrix effects and interference from unwanted elements can also be corrected using calculations (Ivanenko et al. 2003), but these require non-trivial calculations.

2.9 Developing Chemical Signatures of a Toolstone Source

Most archaeologists approach the problem of chemical sourcing by asking the following question: How many different raw material sources (origins of the material) are present in the assemblage? A sample for chemical analysis of artifacts must encompass all the predicted variability in a material that could be attributed to a source or multiple sources, thus the larger the sample the more representative of chemical variation it will be (Shackley 2005). Representation of different source materials is determined by using such multivariate statistical procedures as, principal component analysis, cluster analysis, and/or discriminant function to group related chemical concentrations of artifacts (Glascock et al. 1998). Once element pairs that are reliable indicators driving the elemental group clusters are determined, bivariate plots can be used to determine source groupings (Reuther et al. 2011). However, multivariate statistics involve the interaction of all possible elements that contribute to the strongest chemical groupings representative of sources, and thus are more robust than bivariate pairs. Statistically significant distinct groupings of artifacts are attributed to a chemically similar source group (Coffman and Rasic 2015; Malyk-Selivanova et al. 1998; Reuther et al. 2011).

Elements that are important for distinguishing chemical group clusters that represent source signatures may also be determined by analyzing primary source bedrock materials. Therefore, the elements that are important for distinguishing a distinct primary source will be known, rather than estimating that the variability of the material is represented by the artifacts. Igneous materials have known elements that will work to define source clusters based on a sample of artifacts; however unknown "common toolstone" materials do not have designated identifying elements. Therefore, analyzing primary source bedrock of unknown "common toolstone" is the best practice for sourcing this material.

2.10 Chemical Signatures of Artifacts

The theoretical application of chemical units of artifacts to toolstone sources is an appropriate practice when the chemical units and quantitative rigor is reliable and statistically significant. Generating the chemical signatures of artifacts requires the use of a non-destructive ED-pXRF. Primarily the data collected from the artifacts using this device needs to be comparable to the data collected on any other chemical analytical tool such as WD-XRF, Microprobe, and Neutron Activation Analysis. This requires the data on the ED-pXRF to be calibrated in order for elemental concentrations to be reported in terms of parts per million (ppm) or weight percent, rather than counts of a given element. A calibration is determined for a single element at a time, by comparing the actual values of elemental concentrations in ppm or weight percent of a known standard and the elemental concentrations in raw counts acquired by the analytical device, which in this case is a ED-pXRF. The comparison is made using a regression line, such that the ED-pXRF values are the dependent variable and plotted on the Y-axis, and the known standard values or WD-XRF "true-values" are the independent variable and plotted on the X-axis. The closer the R-value of the regression line is to one, less quantitative adjustments need to be made to correct the calibration to make up for the difference between the actual values and the raw counts. If the values fit the regression line, the regression line may serve as an appropriate calibration such that the point given in raw counts will be associated with a value in parts per million on the regression line and that is the actual value of a given elemental concentration in a sample.

Once artifacts may be appropriately chemically analyzed and reliably assigned to a primary source group then attributes on the artifacts can provide information for why that material was transported.

2.11 Site Sampling Selections

The samples were selected from the three different sites because each site has a different site type designation (Figure 1.1). The four components from these three sites were selected because each contained a large lithic debitage assemblage directly associated with a radiocarbon date corresponding with Denali or Northern Archaic populations. Three components were selected associated with the Northern Archaic Tradition and only one from the Denali Complex because during the time of occupation of Northern Archaic populations there are more dated sites, upland regions such as the Tangle Lakes are more important to human subsistence economies after 6,000 cal yr B.P., and archaeologists have identified a distinctive shift in mobility rounds between the Denali and Northern Archaic Traditions (Potter 2008c)

Each site component was previously excavated and housed at the University of Alaska Museum of the North. Whitmore Ridge Component 2 provided the largest effective sample size for this study with 396 flakes associated with a Northern Archaic date. The other three components had larger dated debitage assemblages, therefore stratified random sampling was used to select a random sample from the Denali component (Component 1) at Whitmore Ridge, the Northern Archaic component at XMH-35, and the Northern Archaic component at the Landmark Gap Trail site. More details on site background and assemblage sample selection is outlined in Chapter 3 and Chapter 4.

2.12 Debitage Analysis

Debitage analysis fits particularly well within the Technological Organizational framework because of the patterned nature of reduction of stone tools and resulting flakes (Carr and Bradbury 2001). Additionally, debitage can represent human behavior at every stage of technological organization from procurement to discard, whereas tools only represent a final product (Andrefsky 2005). Though a tool may have gone through several stages of repurposing and re-use, it is difficult to distinguish the technological and physical path a tool was carried prior to discard. Further, debitage is a control for activities that were performed at each site because there is direct association between human behavior and site activity areas. While, the tools that are produced at a site are often carried off site the byproducts of tool production are often discarded at the site, indicating what types of tools were manufactured.

Debitage analysis focuses on the byproducts of tool production because it concentrates on the debris created from manufacturing a tool (Andrefsky 2005). The debitage can range from large cortical flakes to tiny bifacial thinning flakes. An understanding can be gained from debitage analyses on how a tool was produced, the size of the original nodule or raw material package used as an objective piece, or core, and at what stage a flake was removed from that objective piece (Sullivan and Rozen 1985). Discarded lithic debris or debitage from the reduction of raw material and production of tools is arguably more useful than formal tool analysis for understanding human behavior because it usually occurs in higher numbers (larger sample size) than the formal tools. Additionally, stone tool production follows a pattern of reduction that is finite, such that nothing can be added on to the artifact, material can only be removed in a finite number of ways based on the original size of the raw material nodule (Bradbury and Carr 1999).

Archaeologists have studied reduction sequences through experimentally knapping stone tools (Ahler 1989; Bordes and Crabtree 1969; Bradbury and Carr 1999; Carr and Bradbury 2001). Debitage can be analyzed in terms of individual artifacts but also as aggregates (Ahler 1989; Andrefsky 2005; Sullivan and Rozen 1985). In this study, attribute analysis will be performed on individual flakes that can be interpreted individually or as a population (Andrefsky 2005). Individual Flake Attribute analysis (IFA), outlined by Andrefsky (2005) and Prentiss (2001), was performed in this study. Both metric and qualitative attributes can be recorded on debitage. Metric and qualitative attributes can provide information, such as what types of percussion were used to remove the flake, the stage of reduction, and taphonomy. Ultimately IFA provides methods for measuring variation in lithic debitage assemblages (Prentiss 2001; Sullivan and Rozen 1985). Flake thickness-related measures have been shown to provide statistically significant results for assemblage variability based on a response to raw material source availability (distance) (Newman 1994). Other metric measures of flakes could possibly be deceiving for assessing the degree of use because length and width are highly dependent on raw material nodule size and quality (Dibble 1991); thus, revealing equifinality in using flake size to assess reduction stages and toolstone conservation (Newman 1994). However, size could be useful if non-metric measures such as dorsal scar count were evaluated in association with flake size. The variables and expectations relating to how each attribute of the debitage analyzed should be interpreted with regards to human behavior are outlined below.

Raw Material Variability

Raw material variability may be observed by calculating frequencies of different raw material classes, quality, and chemical classification. If there is lower material richness/diversity and less evenness, most tools are made of one type of material, then the material may have been directly procured (Clarkson 2008). If there is increased richness, such that there is greater diversity of materials present in an assemblage (higher encounter rates with different sources) and increased evenness (no one single material type will dominate the assemblage), then the material may have been obtained through embedded procurement (Clarkson 2008). Richness and evenness will be evaluated by assessing the association of these attributes. The sample size must be larger and more equal between the two sites to be conclusive when comparing richness and evenness between sites.

Technology Type

The association between technology type and raw material type is another test for raw material richness and evenness. The number of different types of activities represented by different materials is an indicator of evenness. Further, if certain activities represented by the debitage are represented by patterned raw material frequencies, then this may signal raw material selection for specific tasks or technology (Kuhn 1995). Activities can be inferred from technology type (Andrefsky 2005; Sullivan and

Rozen 1985). One of these activities is reduction of different types of tools. Early stages of reduction are expected to be closer to a raw material source based on the distance decay model (Bamforth 2006). Bifacial thinning flakes are an indicator of formal technology and bifacial production (Andrefsky 2005). Simple flakes are representative of expedient technology, commonly associated with high raw material availability (Thacker 1996). Decortication flakes are associated with primary and early reduction stages that are expected to occur near a raw material source. The size, completeness, and termination of the debitage can also indicate what activities occurred and the stage in the artifact's life history (Prentiss 2001; Sullivan and Rozen 1985).

Flake type, Modified Sullivan and Rozen Typology (MSRT) and Flake Completeness

Neither of these variable categories require additional inferences to determine what form of technology a flake was derived from. Instead, flakes are grouped into patterns based on descriptive attributes that are not associated with a typological definition (Sullivan and Rozen 1985). Other variables, especially flake size, can condition the number of complete, broken flakes, fragments, and shatter, and must be considered together in an analysis (Prentiss 2001). Patterns of flake completeness categorized by flake size-class can be used to infer reduction stage (Prentiss 2001). Core reduction should be reflected by shatter and proximal broken flakes. A combination of complete, broken, and flake fragments is an indication of core reduction and tool manufacture. High levels of broken flakes (especially if they are the same part of the flake) could indicate post-depositional disturbance or trampling, which can be checked by evaluating correlation between other variables and flake characteristics (Sullivan and Rozen 1985). Contrary to the conclusion of Sullivan and Rozen (1985) that complete flakes are associated with core reduction, complete flakes have been also shown to be representative of tool production (Andrefsky 2005). Understanding the stage of reduction in conjunction with raw material type indicates how far people were carrying the material and how the material was conserved (Bamforth 2006).

Cortex

The amount of cortex present on a flake indicates its stage of reduction, generally based on the distance-decay model and optimization models, cortex will be removed early in the reduction sequence (Mauldin and Amick 1989), in an effort to minimize the cost of carrying unusable material (Wilson 2007a). Therefore, the more cortex present, the closer the assemblage is likely to be to a source.

Terminations

The termination reflects how the energy from a percussor was distributed through the material leading the flake to be removed; as such, it reflects how the flake was removed (Andrefsky 2005; Dibble and Whittaker 1981). It can also reflect the quality of the material, such that high quality fine-grained cryptocrystalline silicates tend to fracture predictably, conchoidally and feather, rather than break in a stepped fracture.

Lipping and Bulb Type

Hard-hammer percussion is believed to produce flakes with salient bulbs, no lipping, and crushed platforms (Andrefsky 2005). Diffuse bulbs and pronounced lips are thought to be associated with soft-hammer percussion (Andrefsky 2005). However, since both of these features relate to conchoidal fracturing properties, it is possible that the quality of the material can affect the lipping and bulb type independently from the method of percussion. Therefore, patterns between raw material type and lipping and bulb type can indicate raw material quality, variability, and selection for particular forms of percussion.

Platform Type

Variables relating to the platform and platform preparation have been shown through experimental archaeology to be under the direct control of the flintknapper (Dibble 1997). Platform preparation can address questions about technological efficiency, resource economy, and mobility (Dibble 1997). Crushed platforms are associated with hard hammer percussion (Andrefsky 2005). Flat, simple platforms are associated with non-bifacial tools and removal from unidirectional cores (Andrefsky 2005). Complex faceted cores are extremely time consuming to prepare and can indicate formal planned technological preparation (Andrefsky 2005:94).

Dorsal Flake Scar Count

Dorsal scar count can be affected by several variables including: size of the piece being worked, flaking method, raw material quality, and technology being produced (Andrefsky 2005). Despite the equifinality in interpreting flake scars it has been demonstrated as a good indication of reduction stage, such that fewer flake scars occur on the dorsal surface of an early stage flake as opposed to more on a later stage flake (Andrefsky 2005).

Size, Weight and Thickness Class

Metric attributes of size can mean several things (as described about dorsal scar count); a pattern of distance-decay relating to the size/amount of material as it is transported away from a raw material source, generally and consistently decreases (Renfrew 1977).

Chapter 3 Site and Regional Background

3.1 Study Area

TaxatsbEnE' is the Ahtna placename for the Tangle Lakes (Zinck and Zinck 1976). The study region is defined by the boundaries of the Tangle Lakes Archaeological District (Figure 1.1). It is a 226,660 acre area, directly south of the Alaska Range in the Amphitheater Mountains Upper Delta River Valley, at approximately 3,000 ft elevation (Bowers et al. 1983; Mobley 1982; Schweger 1981; Taylor et al. 2016). The district encompasses land north and south of the Denali Highway between mileposts 15 and 32, in Alaska State Quadrangles Mount Hayes A4 and A5 (Wang et al. 2008). The Tangle Lakes are a 26-mile chain of lakes connected by streams that form the headwaters of the Delta River. The district has been listed on the National Register of Historic Places since 1971, and is managed by the Bureau of Land Management and the State of Alaska Department of Natural Resources (Mobley 1982; VanderHoek 2011). Specifically, this project focuses on several archaeological sites within the Tangle Lakes Archaeological District, both north and south of the Denali Highway between the Landmark Gap Lake valley and the Long Tangle Lake valley (Figure 3.1).

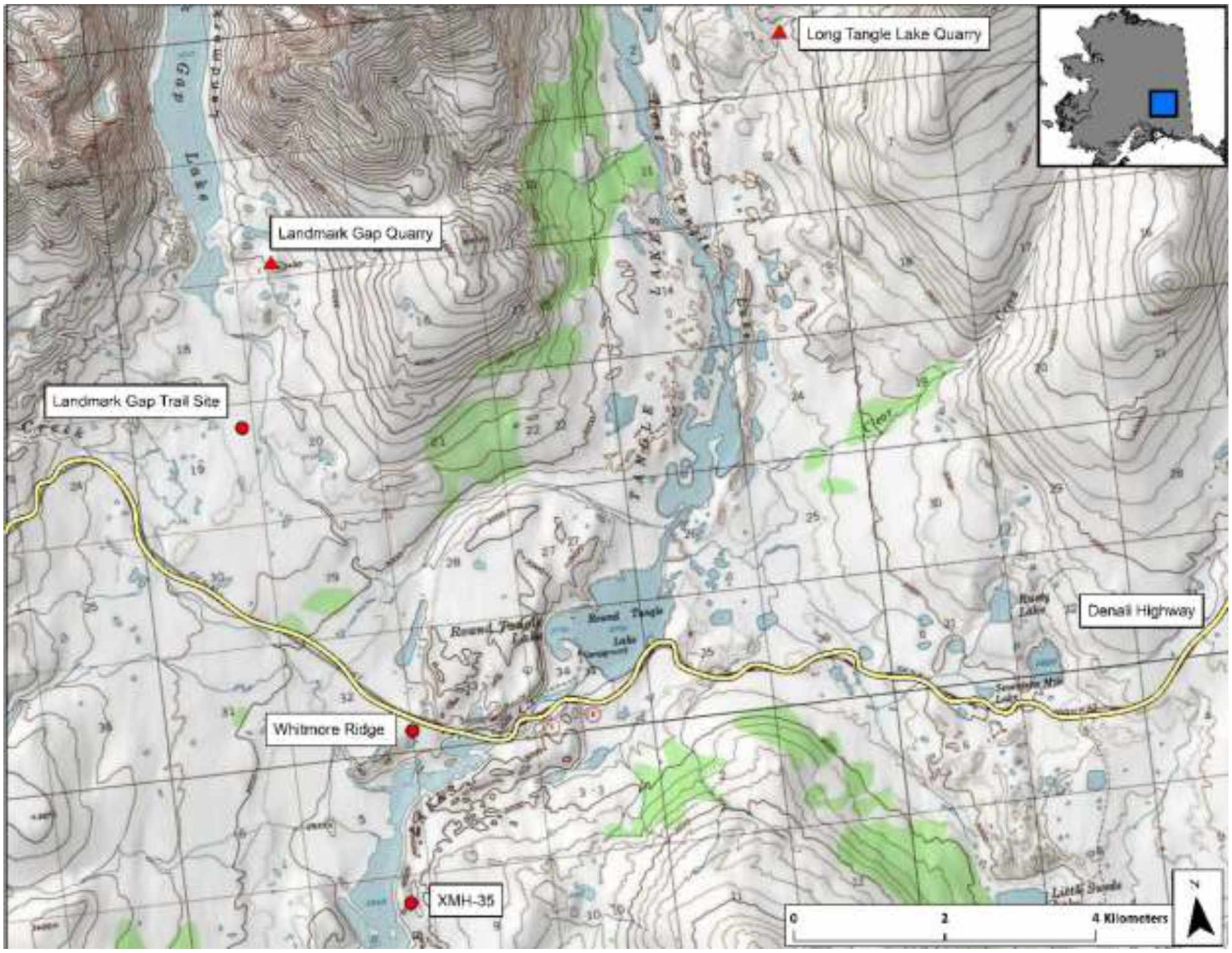

Figure 3.1 Study area within the Tangle Lakes Archaeological District (TLAD). The specific area within the Tangle Lakes region that is focused on for this project included the five archaeological sites: The Landmark Gap and Long Tangle Lake prehistoric quarries, Whitmore Ridge site, the Landmark Gap Trail site, and XMH-35 site.

3.2 Geology

The Tangle Lakes study region is within the Eureka Creek geological area, sub-region Amphitheater Mountains (Rose 1966; Stout 1976). The Amphitheater Mountains (Figure 3.1) in the northern portion of the Tangle Lakes Archaeological district are geologically complicated, but comprised mostly of Triassic and pre-Triassic volcanic, volcaniclastic, and sedimentary rocks intruded and overlain by Triassic mafic volcanic and intrusive (Bowers et al. 1983). The predominant unit is a thick mafic (basaltic) sequence, locally called the Amphitheater basalt and known more regionally as the Nikolai greenstone (Blodgett 2002). Greenstone is a general term for slightly to modestly metamorphosed basaltic rocks that includes intrusive and extrusive varieties. Early workers, such as Rose (1966) and Stout (1976) considered the voluminous gabbroic (mafic) intrusions into the greenstones and older rocks to be considerably younger than the greenstones. However, a considerable body of radiometric ages, summarized in Lande et al. (2015) indicate that the mafic extrusive and intrusive rocks are essentially contemporaneous; some gabbro is younger than basalt and vice-versa.

The only detailed geologic map of the Landmark Gap area is that of Stout (1976). Figure 3.2, modified from Stout (1976) shows the quarry area is dominated by a unit he designated the Tangle Lakes Formation for which he documented a Triassic age. The lower portion (and majority) of the unit consists of 'well-bedded siliceous tuffs and tuffaceous fine-grained sediments', abundantly intruded by mafic sills (intruded parallel to bedding), as seen on Figure 3.2 and the related cross-section (Figure 3.3). The unit possesses well-defined layering that usually dips to the N at moderate (30-50°) angles (Figure 3.2, 3.3). The voluminous mafic intrusions have caused 'contact metamorphism' of the Tangle Lakes formation, that is, recrystallization at relatively low pressure. Such recrystallization makes these rocks harder and 'tougher' than normal sedimentary rocks.

Subsequent workers, such as Nokelberg et al. (1982) ignored Stout (1976) and designated the unit Paleozoic. Blodgett (2002) indicated there was no evidence for a Paleozoic age. The importance of this controversy is that the Tangle Lakes Formation is quite different from the Paleozoic units with which it has been lumped; the latter are primarily sedimentary rocks lacking volcanic components. Due to this problem, it's unclear how far the Tangle Lakes Formation extends outside of the quarry areas.

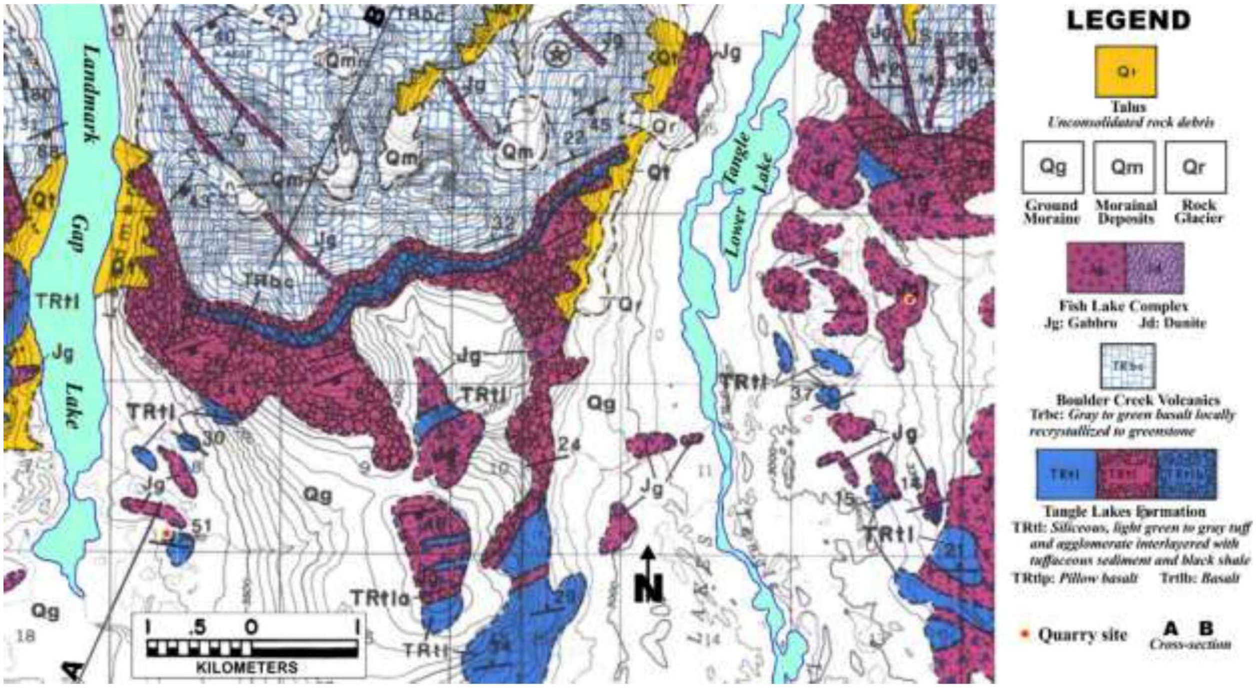

Figure 3.2 Detailed geologic map of the immediate quarry areas. The graph is modified from Stout (1976) by Rainer Newberry. Note that rocks of the Fish Lake Complex (Jg and Jd) are now known to be late Triassic (and not Jurassic).

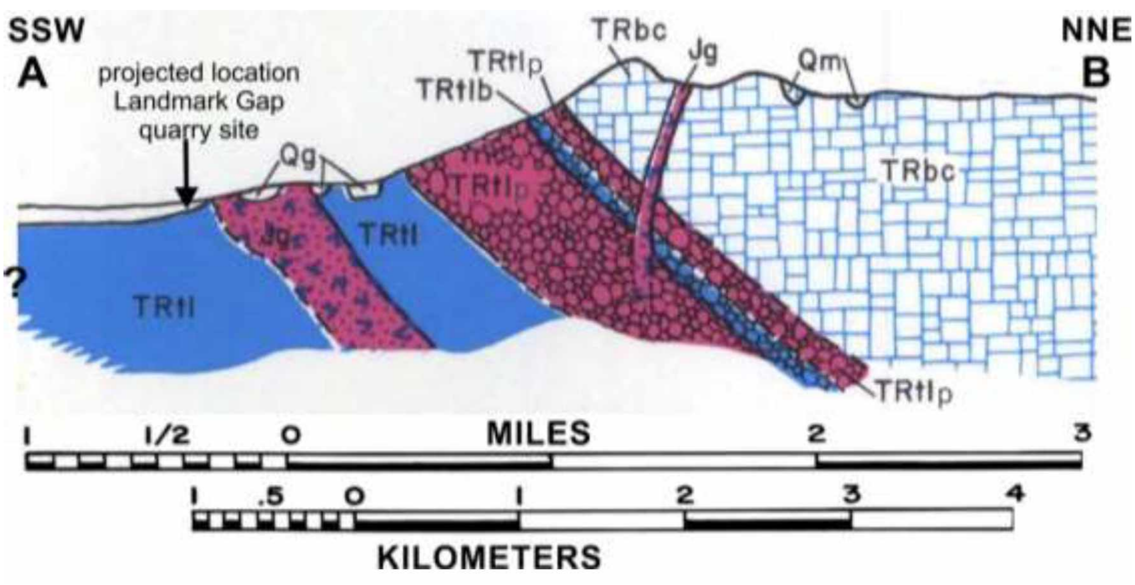

Figure 3.3 Geologic cross-section A-B nearly through the Landmark Gap quarry site. The cross-section modified from Stout (1976) by Rainer Newberry. See Figure 3.2 for cross-section location and key to the geologic units. Note that the projected location of the Landmark Gap quarry is about 100 m below the contact with a 0.5 km thick gabbroic sill.

3.3 Modern Environment

Currently, the Tangle Lakes Archaeological District study area is comprised of two physiographic upland sub-regions, which have slightly different environments. It has been documented that hunter-gatherers tend to occupy the margins of ecotones because of the variety of resources these areas provide (Gelvin-Reymiller and Potter 2009; Larsen et al. 2008). Figure 3.4 shows that the northern portion of the Tangle Lakes vegetation is characterized by alpine tundra above tree-line, and the southern portion is characterized by open spruce woodland (Ager and Sims 1981; West et al. 1996). Specifically, vegetation consists of willow (*Salix*), balsam poplar (*P. balsamifera*), Spruce (Picea), paper birch (*Betula papyrifera*), alder (*Alnus*) and *Spirea*, in addition to grasses, forbs, herbaceous shrubs (*Artemisia*), mosses (Ager and Sims 1981; Bowers et al. 1983; Wang et al. 2008; West et al. 1996). Tree-line or the edge of the alpine tundra occurs at about 950m (Ager and Sims 1981). Low tundra vegetation in higher areas includes alpine bearberry (Arctostaphylos *uva-ursi*), blueberry (*V. uliginosum*), cranberry (*Vaccinium vitis idaea*), ground willow (*Salix* spp.), mountain avens (*Dryas octopretala*), and juniper (*Juniperus* spp.), (West 1981).

The climate of the region is continental with cool, wet summers, and dry, cold winters, but with infrequent fires (Gillispie 1992; Wang et al. 2008). The upper Copper River Valley and plateaus near the Alaska Range experience greater temperature variation than the lower portions of the valley near the Chugach Mountains, which reflects the interior continental climate (de Laguna and McClellan 1981). Subsequently, the Tangle Lakes plateaus are characterized by less cloud cover, humidity, and precipitation with snow cover generally from mid-November through mid-April (de Laguna and McClellan 1981). U.S. Climate Data (2018) listed: from 1961 – 1990 the average annual high temperature was 2.1°C (35.8°F) and the average low temperature was -8.7°C (16.3°F). The coldest average low temperature was recorded for both December and February as -21.7°C (-7°F). The warmest average high temperature was recorded for July as 66° F. Weather records from Paxson Lake, approximately 30 miles southeast of the Long Tangle Lake, in the summer range from 1.7° C (35.1° F) to 17° C (62.6° F), and in winter range from -33° C (-27.4° F) to 1.1° C (33.9° F), (Gillispie 1992). Mean annual average air temperature in the winter is -4.8° C, and mean July temperature is 11.3° C (Ager and Sims 1981). Annual precipitation is 43 cm (17.2 inches) and snowfall accumulation in the highlands can range between 50-100 cm (20-40 inches) (Ager and Sims 1981; Gillispie 1992). The sunlight ranges from five hours in December to 19 hours in June (Wang et al. 2008).

Contemporary wildlife includes a diverse assortment of 33 species of mammals and 59 species of birds (Gillispie 1992). These mammals, especially those with seasonal migration/congregation patterns such as caribou, moose, and Dall sheep, have been ethnographically important to indigenous subsistence (Gillispie 1992; Zinck and Zinck 1976). Though moose inhabit the Tangle Lakes, they are less abundant than caribou. The Nelchina caribou herd occupies the Tangle Lakes Archaeological District in both the summer and winter but is most present in the winter. In the Fall 2016, 46,673 individuals were documented within the Nelchina caribou herd. Since 1953, there has been a significant boom and bust cycle for the Nelchina herd population such that in 1953 and the 1970s there were under 10,000 caribou in the herd, whereas in 1962 there were over 70,000 (Frate et al. 2017). Other mammals that are common in the area include grizzly bears, coyotes, wolverine, and seen less often, the wolf (West et al. 1996; Zinck and Zinck 1976). Ground squirrels, pikas, and marmots are common small mammals that occupy the mountainous areas (Zinck and Zinck 1976). Ptarmigan occupy the region year-round, while other avian species such as red-throated and common loons, jaegers arctic terns, eagles, falcons, hawks, and owls (West et al. 1996; Zinck and Zinck 1976). While there are no anadromous fish in the Tangle Lakes Archaeological district, salmon are available to the south and the southeast in the Gulkana River watershed; the native species to the area include trout, arctic grayling, and char (Gillispie 1992; West et al. 1996). Important fur bearing mammals that are native and abundant throughout the region include muskrat, mink, marten, red fox, beaver, and lynx (Gillispie 1992; Zinck and Zinck 1976).

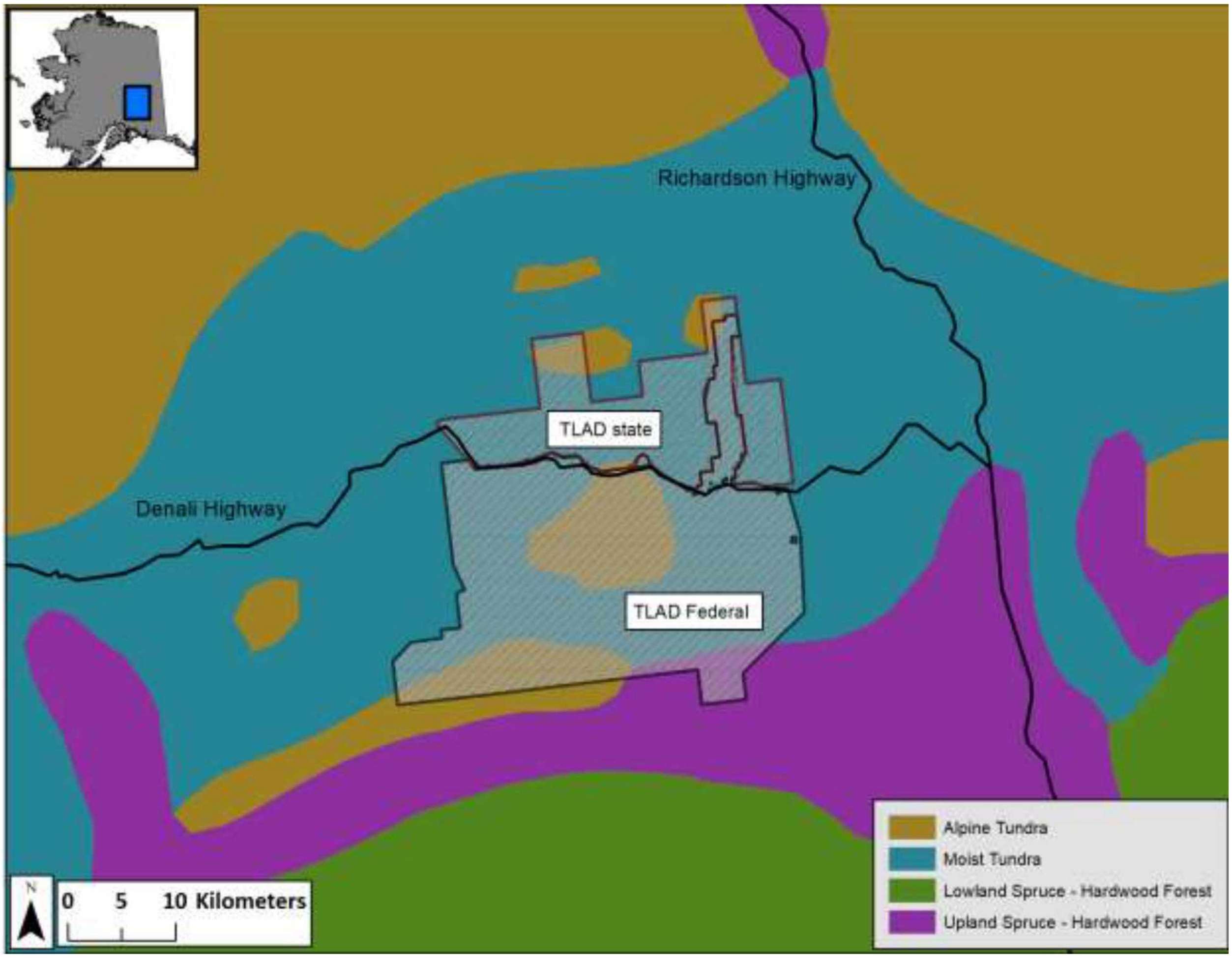

Figure 3.4 Ecosystem divisions encompassed within the Tangle Lakes Archaeological District.

3.4 Paleoenvironment

The Tangle Lakes paleo-environment is best understood in relation to Eastern Beringia in the context of human occupation. Eastern Beringia's boundaries are defined as between the Alaska Range and the Brooks Range, specifically characterized by the Yukon-Tanana Uplands and lowlands made up of networks of tributaries to the Tanana, Nenana, Yukon, and Kuskokwim Rivers, which have been unglaciated for the last 50,000 years (Erlandson et al. 1991). The habitability of this region coincides with the exposure of the Bering Land Bridge, which emerged during the Last Glacial Maximum around 20,000 yr cal B.P. when global sea levels fell (Bever 2012; Erlandson et al. 1991; Hoffecker and Elias 2007). It existed until sometime before 12,000 yr cal B.P. when sea levels rose and it was submerged (Bever 2012; Erlandson et al. 1991; Hoffecker and Elias 2007). However, this period of exposure of the

Bering Land Bridge only may have coincided briefly with the initial deglaciation of the Tangle Lakes region. The Tangle Lakes Region showed evidence of a proglacial lake, an indication that deglaciation occurred, as early as 11,800 +/-780 radiocarbon yr B.P. (between 13,000 and 15,000 cal yr B.P.) (Schweger 1981). This area was vegetated with tundra and *Betula* shrubs as early as 12,000 radiocarbon years ago (approximately 14,000 cal yr B.P.; (West 1981). Recession of alpine glaciers is dated to 12,000 cal yr B.P., concurrent with the Bering Land Bridge submerging (Bever 2012).

The paleoenvironment of the interior regions of Eastern Beringia during the Last Glacial Maximum was cold and dry with an extensive herbaceous tundra cover. Once deglaciation began and the Bering Land Bridge decreased, a warmer and moister climate promoted the spread of a shrub tundra vegetation during the Allerød, around 14,000 cal yr B.P. (Bever 2012; Guthrie 2001). Subsequently, the onset of the Allerød corresponds with the first known traces of human occupation of Eastern Beringia, 14,300 cal yr B.P. The Allerød persisted until approximately 12,800 cal yr B.P. and characterized by increasing growth of shrub tundra and birch and the presence of megafauna (mammoth, horse, and a small number of bison), though declining as steppe-tundra conditions changed (Guthrie 2006; Hoffecker and Elias 2007). These conditions lasted until the onset of the Younger Dryas around 12,800 cal yr B.P. The Younger Dryas is characterized by a period of cold/dry climate that lasted until around 11,700 cal yr B.P. (Graf and Bigelow 2011). The Younger Dryas climate shift is associated with a shift from herbaceous tundra to a denser shrub tundra that had a significant herbaceous component (Bigelow and Edwards 2001). The mammoth was likely the first of the megafauna to go extinct prior to the Younger Dryas (Mann et al. 2015). The Pleistocene horse (*Equus* cf. *feris)* populations were extinct sometime during the Younger Dryas but alternatively bison populations increased (Bigelow and Powers 2001; Guthrie 2006; Mann et al. 2015). At the end of the Younger Dryas, also marking the transition from the Late Pleistocene to the Early Holocene, a warmer/moister climate returned, often referred to as The Holocene Thermal Maximum bracketed by the dates between 10,000 and 9,000 cal yr B.P. (Kaufman et al. 2004). This period marked the shift to birch, spruce and alder vegetation. Likewise, most megafauna species went completely extinct but there was the presence of bison, wapiti, and moose, and evidence of human use of salmon in the archaeological record (Bigelow and Powers 2001; Guthrie 2006; Halffman et al. 2015). There were several more warming and cooling climatic events after the height of the Holocene Thermal Maximum (9,000 cal yr B.P.), but by around 7,000 cal yr B.P. the environment was generally more stable across interior Eastern Beringia and the boreal forest was fully established by around 6,000 cal yr B.P. (Bever 2012). These climatic shifts affected vegetation and faunal populations, which, in turn, is also believed to impacted human occupation of the environment (Bigelow and Powers 2001; Potter 2008b).

When vegetation established itself after deglaciation in the Tangle Lakes, the succession of general regional climatic events affected Tangle Lakes in corresponding manner. Dates of vegetation and climate data cited from Ager and Sims (1985), Schweger (1981), and Begét and others (1991) were not reported in calibrated years B.P. (cal yr B.P.); in calibrated dates follow the dates cited from these sources when possible. The modern vegetation of Tangle Lakes described above has persisted for the last 4,700 years, with a 13-18% increase in spruce (*Picea*) beginning around 3500 years ago based on the upper 3.4 meters of pollen cores (Ager and Sims 1981:85). *Picea* provide interesting vegetation fluctuation information, as the first records of spruce initially colonizing Tangle Lakes occurred 2500 – 3000 years post deglaciation around 9100 years ago. but essentially died out in the local region between 9000 and 4700 years ago. (Ager and Sims 1981:85). This Mid-late Holocene reemergence of the spruce is associated with a surprisingly cool but moister climate. Schweger (1981) analyzed radiocarbon and pollen samples from extracted from proglacial lake sediments present in the form of a high-level shoreline contour and high-level lacustrine sediments from an archaeological site (XMH-287) on the side of an esker ridge deposited correlative with the high-water proglacial lake stage (Gillispie 1992). The high levels of the lake are associated with the period directly following glaciation in the upper Delta Valley and ice mass stagnation (Schweger 1981:97). Dates bracketing the high-level lake shore sediments are 11,800 +/-750 – 9,100 +/-80 years ago (14,114 +/-1046 cal yr B.P. – 10,304 +/-88 cal yr B.P.), indicating that the upper Delta Valley glacial advance must have stagnated prior to 11,800 +/-750 years ago (14,114 +/-1046). The earliest post-glacial vegetation during the period recorded by Schweger (1981) included a treeless low shrub-herb tundra with dwarf birch (*Betula nana, B. glandulosa),* Ericales (*Empetrum* and Ericaceae), and willow (*Salix* spp.) (Ager and Sims 1981). Ager and Sims (1981) reveals that later vegetation from 4560+/-170 years ago (5220 +/-229 cal yr B.P.) past 2880 +/-70 years ago (3032 +/-160 cal yr B.P.)was dominated by *Picea, Betula, Alnus, Salix,* and small amounts of Ericales.

3.5 Regional Stratigraphy

The generalized Tangle Lakes stratigraphy in archaeological contexts includes at least three distinct soil horizons (A, E, and B Horizons) that developed in silt and gravel deposits and a layer of tephra from the Hayes volcanic eruption (Figure 3.1.5; Tom Gillispie, personal communication 2018). The Hayes Tephra has provided the greatest relative dates for site chronology in the region and has dates between 3865+/-45 years ago (4298 +/-82 cal yr B.P.) from a buried A horizon at XMH-239 and 3660+/-125 B.P. (4011 +/-173 cal yr B.P.) from a modern A horizon at XMH-384 (Begét et al. 1991). According to Schweger (1981) the most simplified description of the stratigraphic soil sequence of Mt. Hayes A5 resulted from the stabilization of gravel ridges post-glaciation, and subsequent development of a Late Glacial soil, which serves as the prominent local paleosol horizon, that was later buried by rapid deposition of eolian silt in the Tangle Lakes Archaeological District. The generalized regional stratigraphy is documented as follows: 0-10 cmbs modern organic horizon, 10-12 cmbs A horizon silt, 12-14 cmbs E horizon silt, 15-35 cmbs in some areas Hayes Tephra, 16-35 cmbs B horizon silt, 36-38 cmbs A horizon silt, 38-40 cmbs E horizon silt, 40-50 cmbs B horizon silt, 50-52 cmbs A Horizon silt, 52-54 cmbs E horizon silt, 54-60 cmbs B horizon, 60-100 cmbs lacustrine sand in some areas, 60-100 cmbs glacial deposits in some areas (Figure 3.5; Tom Gillispie, personal communication 2018).

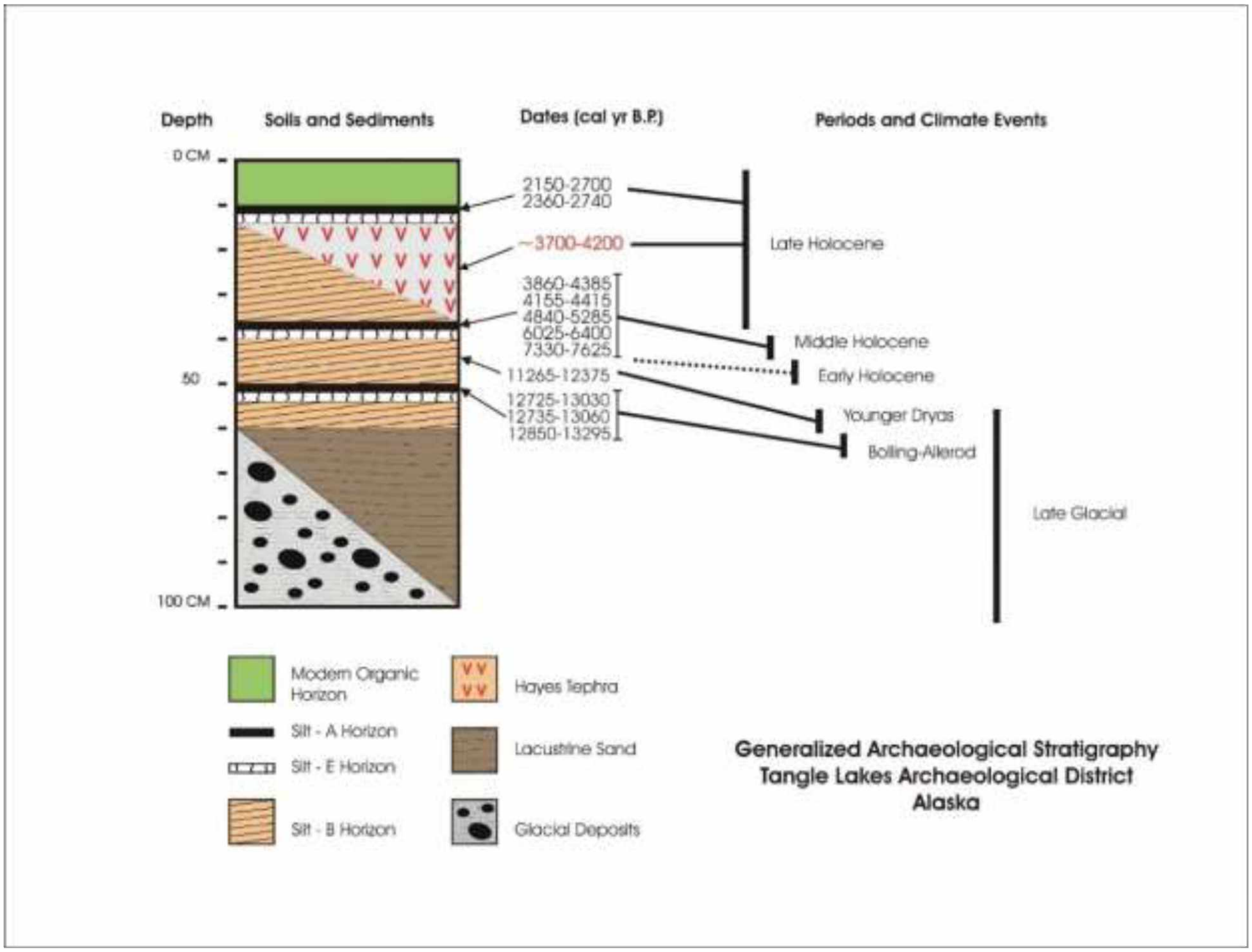

Figure 3.5 Generalized Archaeological Stratigraphy of Tangle Lakes. The stratigraphic graphic was provided by Tom Gillispie, personal communication, February 26, 2018. The stratigraphy is based on information from Tom Gillispie's fieldwork seasons in 1989, 1991, 1995, and 2015, and information from West (1996), Davies et al. (2016), Dixon (1985), and Dilley (1988).

3.6 Cultural Background

The Central Ahtna Athabascans, specifically the Gulkana-Gakona Band, traditionally occupied the Tangle Lakes region on a seasonal basis. The region was used for big game hunting, such as caribou. It is also possible that this was an area that was traveled through during trade between the Dena'ina, Ahtna, and Tanana (Salcha Band). There are traditional Athabascan trails throughout the area that may be associated with ethno-historic trade between these cultural groups (Gillispie 1992).

3.7 Ethnography of the Tangle Lakes Region

The Tangle Lakes region is located within the Ahtna Athabascan cultural linguistic area, and encompasses a number of archaeological sites that are important in Ahtna prehistory (Reckord 1983). Ahtna ethnography and the archaeological record suggest the area was occupied repeatedly but not continuously, from approximately 13,000 cal yr B.P. through modern times (Dixon 1985; Potter 2008c; West 1981). In recent history, there are no archaeological sites with reliable dates within the last 600 years (Potter 2008c); however, there are a number of surficial lithic scatters in the area. Further, ethnohistoric accounts of Ahtna prehistory describe the Tangle Lakes as seasonal spring and fall caribou hunting grounds for the Gulkana group (Reckord 1983). Further, Ahtna oral history describes Paxson Lake area as the site of a traditional permanent winter village in the last century and the site of an ancient interclan battle (Reckord 1983). The context of this battle is based on clan ownership of the hunting and fishing rights to Paxson Lake, such that the Udzisyu clan, upon request, would grant other Ahtna families or clans use rights of the lake according to Ahtna law. Disregard for the law by the Naltsiine clan resulted in the battle, resolved by a potlach and dividing control of Paxson Lake between the Naltsiine and Udzisyu (Reckord 1983). Archaeological sites around Paxson Lake offer an additional line of evidence for this story, as it is the location for several village sites and caribou kill sites (Reckord 1983). Ahtna would spear swimming caribou in Paxson lake from skin canoes (Reckord 1983). Proximity of Paxson Lake to the Tangle Lakes and similarity in resources, likely indicates that the Tangle Lakes area was utilized and controlled in a similar way to the ethnohistoric accounts at Paxson Lake. According to Ahtna oral tradition, a long caribou fence was used to funnel migrating caribou into the Tangle Lakes, where they were speared by hunters in canoes (Reckord 1983). Similar to Paxson Lake, archaeological sites such as caribou kill sites, fish camps, canoe portages, and other camps have been located in the Tangle Lakes archaeological district (Reckord 1983).

In the nineteenth century Ahtna territory spanned from Mentasta Mountain to the entrance of Denali Park in the north, the Wrangell Mountains and Chitina River in the east, and drainage basins of the Matanuska, Talkeetna and Susitna Rivers in the west (de Leguna and McClellan 1981). However, these boundaries were often difficult to define and slightly amorphous due to social mechanisms, such as intermarriages (Reckord 1983). The major territorial boundaries were between the Lower, Middle, Western, and Upper Ahtna, which each had designated areas for hunting, fishing, and berry-picking. An uninvited individual speaking a different dialect could be killed (de Leguna and McClellan 1981). The

Tangle Lakes region is specifically associated with the Middle Ahtna, Gulkana-Gakona Band territory, which spanned from the Alaska Range in the north to present day Glennallen in the south. Gulkana-Gakona band specifically occupied drainages of the Tazlina-Mendeltna, Gakona, Gulkana, and upper Susitna rivers (de Laguna and McClellan 1981).

Based on information from the nineteenth century Ahtna settlements *(qayax)* were winter villages or hunting/fishing camps. Winter villages consisted of a maximum of nine multifamily houses distributed over several miles established under a leading chief. Settlement clusters up to a 20-mile radius spoke a distinctive dialect. The leadership of the chiefs varied based on their wealth and band allegiances (de Leguna and McClellan 1981). Ahtna winter houses were rectangular with an excavated floor and walls built with vertical posts. Cooking took place around a central fireplace. There were also smaller moss houses built in the woods and out of the wind for trapping and hunting (de Leguna and McClellan 1981).

Subsistence for the Middle Ahtna groups consisted largely of muskrat, caribou, and Dall sheep in the Alaska and Wrangell mountain ranges. The Ahtna oriented their calendar and subsistence around a two-part year: summer, beginning with breakup in late April; and winter, beginning in November. Subsistence related mobility included summer salmon camps, to summer upland meat camps, to river drainages in the fall for trapping and hunting, then families gathered in winter houses near the summer fish camps. Ahtna exploited small game in transitions between these locations and foraged for game and water in the later winter months (de Leguna and McClellan 1981). The spring and fall caribou migrations and salmon runs were the most important subsistence related items. However, the Ahtna also traditionally procured and ate moose, caribou, goat, sheep, black and grizzly bear, lynx, beaver, muskrats, game birds, porcupine, rabbit, ground squirrels, fish and some vegetable foods. The Ahtna had traditional practices for handling and preparing the procured animals, some of which was gender specific (de Leguna and McClellan 648). In the Ahtna culture anyone was free to produce any tool necessary for critical gender-specific tasks, the only restricted material was native copper. The native copper had limited distribution and was controlled by the Lower Ahtna. The material required religious precautions to acquire and specialized knowledge of how to shape it (de Leguna and McClellan 1981).

The Ahtna, specifically the Lower Ahtna, were critical for trade between indigenous communities between the interior and coastal groups. They were involved in ancient trade networks between the Eskimo, other Athabascan groups, Eyak, and Tlingit (de Leguna and McClellan 1981; Reckord 1983). Ahtna oral history refers to trade in the late summer with the Tanana (Salcha) in Isabel Pass, which is only 11 miles north of Paxson (Reckord 1983). When exchanges were carried out in Isabel Pass Ahtna traders could take boats of furs and other goods down the Gulkana River and redistribute goods throughout the rest of Ahtna territory using the Copper River (Reckord 1983). Entering Tangle Lakes prior to Euro-American roads and trails was only possible by foot or river travel. Gulkana people would go up the Gulkana River to Tangle Lakes, Maclaren River, and Valdez creek; and traditional Ahtna trails connected these locations with Fish Lake and Ewan Lake (Zinck and Zinck 1976). The ancient trade connections recorded ethnographically could bear significance on prehistoric trade through the Tangle Lakes of ancient materials and goods, such as obsidian, native copper, fur and meats, and possibly the metacherts and metatuffs local to the Tangle Lakes.

The first extensive contact between the Ahtna and non-indigenous explorers occurred between 1898 – 1899 with gold rush prospectors and military expeditions of Glenn and Abercrombie in 1900 (de Leguna and McClellan 1981). The population of the Upper and Western Ahtna was estimated to be 75 individuals between 1898 and 1899. By 1810, and likely a decade prior, trade was active between Russians and the people occupying the Copper River, likely the Ahtna (Reckord 1983). The Ahtna had developed a reputation of hostility towards European expeditions, which are also associated with Ahtna accounts of cruelty from Russian explorers and traders (Reckord 1983). It is suggested that by the first decade of the 1800s, Ahtna were participating in Russian fur trade, facilitated by the Chugach, and their pre-contact lifeways were shifting to accommodate demands of fur trade (Reckord 1983).

3.8 Cultural History and Lithic Technology

The Tanana, Susitna, and Copper River basins represent a region that has evidence of the longest continuous human occupation in the Western Hemisphere (Potter 2008c). The first evidence for human occupation in interior Alaska dates approximately to 14,300 yr cal B.P. (Holmes 2011). This time period is associated with stone technological forms characterized by microblade-core production from a prepared biface, similar to the Yubetsu and Dyuktai core and blade production technique typical to older occupations in Siberia (Hoffecker 2011; Holmes 2011). The earliest occupation of deglaciated areas south of the Alaska Range has been recorded from the Phipps site in the Tangle Lakes; the site is associated with the Younger Dryas with a radiocarbon date of 10,200 +/-280, which is approximately

11,910 +/- 480 cal yr B.P. (Graf and Bigelow 2011; Hoffecker et al. 1993; Schweger 1981). Dated components exist in the Tangle Lakes from 11,910 +/- 480 cal yr B.P. through 10,000 cal yr B.P., with a distinct break in occupational components until 6,200 cal yr B.P. (Potter 2008c). It is not likely that this break is a result of a small sample size, but rather a shift in land-use strategy because the re-emergence of sites around 6,200 cal yr B.P. is associated with the Northern Archaic technological trend (Potter 2008c). The area was occupied continuously since 6,200 cal yr B.P., with a brief period of time between 4,000 and 3,000 cal yr B.P. with no dated site components (Potter 2008c). Ahtna ancient oral history suggests continuous use of the Tangle Lakes within the last 600 years despite the lack of dated components. The lack of dated components is likely due to minimal soil deposition, and surface lithic scatters making it difficult to obtain a recent radiocarbon date.

Due to these possible inter-continental technological connections, interior and central Alaska have been of great interest for developing a cultural chronology (Shott 2013). Unfortunately, interior Alaska is a vast region, most areas lack accessibility for surveying, known sites often lack reliable dates and stratigraphic integrity due to permafrost and forest fires, and lithic technology is not clearly patterned from a cultural-historic perspective (Bever 2006). Therefore, archaeologists been interested understanding the causes of variability of lithic assemblages and how they relate to cultural variability and mobility in Eastern Beringia from the Late Pleistocene through Mid-Holocene.

However, it is important to be familiar with the cultural-chronological complexes because two cultural periods are referenced in this thesis that delineate major technological shifts associated with established Early and Mid-Holocene time periods. The cultural-chronological categories used in this thesis include the Denali Complex or Denali Period, and the Northern Archaic Period. The Tangle Lakes region's association with the establishment of the Denali Complex technological pattern makes it an important region to include in the discussion of Eastern Beringian techno-cultural chronology.

Frederick West identified and defined the Denali complex as a cultural group based on an ethnographic model of Northern Athabascan cultural cohesion and the similarity between lithic technology at the estimated contemporaneous sites, the Campus site, Teklanika West and East, and Donnelly Ridge (West 1981). Denali complex site components are thought to occur between 10,700 and 7,000 B.P (approximately 12,000 – 8,000 cal yr B.P.) which is close to the dates West (1981) came up with looking at Tangle Lakes Denali Complex sites (Coffman 2011). He defined the typological diagnostic markers of the Denali Complex as distinctive wedge-shaped microblade cores with unidirectional blade removals from one edge only, burins manufactured on flakes ("Donnelly burins"); biconvex bifaces (hypothesized functioning as knives), flat topped end scrapers on flakes, and large blades and blade-flakes (West 1981). This complex was the first instance of proposed technological connection with Siberia and the Old World (West 1981). Most notably, in West's (1981) early studies, 16 Denali complex sites were located in the Tangle Lakes region, several probable Denali complex sites in the lower Delta River Valley and Tanana Valley, and Nenana Valley (notably Component II of Dry Creek Site); instances of the Denali Complex were hypothesized for Beluga Point in the Upper Cook Inlet and Paleoarctic tradition sites in Arctic Kobuk River or Seward Peninsula defined by D. Anderson, such as Akmak, Kobuk, and Trail Creek Cave 2 sites (West 1981).

There have been instances when archaeologists have disagreed about the complex assignment of a several sites (Potter 2011). Assigning components to cultural complexes based on the presence or absence of microblades is problematic because of the persistence of microblade technology through time since the earliest occupation in Eastern Beringia, 14,000 cal yr B.P. (Potter 2008c). Therefore, this research references the Denali Complex as a general temporal technological trend with particular presence of distinctive microblade technology, though absence of microblade technology does not necessarily exclude a site from being associated with the Denali Complex. The persistence of microblade technology and the apparent variability in technological assemblages have spurred archaeologists to investigate causes of the variability (Coutouly 2012; Potter 2011; Wygal 2011).

The other major temporal-technological trend referenced in this research is the Northern Archaic Period. Dates reported by Dixon (1985) are not calibrated dates. The Northern Archaic is thought to appear in interior Eastern Beringia rather suddenly around 6,000 years ago as an adaptation to the boreal forest (Dixon 1985). It is characterized by side-notched projectile points, end scrapers, elongate and semi-lunar bifaces, boulder chip scrapers, large unifaces, notched pebbles, hammerstones, and choppers, and tentative lack of microblade technology (Dixon 1985). Notably, Tangle Lakes Denali complex sites seem to have been "abandoned by Denali hunters" around 8,200 ago and a hiatus in the archaeological record before the appearance of Northern Archaic assemblages around 6,000 years ago (Dixon 1985). This hiatus is also recognized at Healy Lake Village Site in the Tanana Valley (Erlandson et al. 1991). However, more recent cultural resource management survey work has filled in the gaps in the missing data, showing that this hiatus was due to sampling bias (Potter 2008b). Instances when microblade and Northern Archaic assemblages appear to be mixed, it is argued that there may have been a transitional period between 8,500 and 6,000 cal yr B.P., and then there is clear evidence of an established Northern Archaic Tradition from 6,000 – 2,000 cal yr B.P., prior to the Athabascan tradition which began around 1,500 cal yr B.P. (Holmes 2008).

Hypotheses for the convoluted relationship between technological types range from the presence of different contemporaneous ethnic/cultural groups (Dixon 1999; West 1981; Yesner and Pearson 2002), to migration (Bever 2012; Vasil'ev 2011), to diffusion (West 1981), to acculturation or replacement of technology (Clark 2001), to different technologies being employed based on differing site function and technological organization response to economic and mobility strategies (Goebel 2011; Potter 2008a; Potter et al. 2014), to adaptive responses to ecological change (Graf and Bigelow 2011; Potter 2008c; Wygal 2011); see discussion in Potter (2008b). Debates about causes of assemblage variability in Eastern Beringia are centered around two main techno-temporal trends: the lack of clear patterning between potential cultural-chronological categories and overall assemblage variability during the late Pleistocene/Early Holocene; and the sudden occurrence of the Northern Archaic Tradition and minimization of the long lasted microblade technology. The late Pleistocene is a temporal boundary associated with Eastern Beringian prehistory between 14,300 cal yr B.P. and 11,700 cal yr B.P. when there is more technological complex diversity (Bever 2006; Potter 2008b). The time between 11,700 and 6,000 cal yr B.P. is the Early Holocene and is associated with less technological variability and stronger tool types as chronological markers that could be associated with an Early Holocene Denali Complex (Bever 2006; Potter 2008b). The time between 6000 and 1000 cal yr B.P. associated with the Northern Archaic is called the Mid-Holocene (Potter 2008b).

Several studies have suggested variability in lithic technology, especially associated with the Denali Complex during the Early Holocene, is based on site function, such that technological needs differ and are represented by different site functions, like residences or "bluff-top lookout" sites (Dixon 1985; Holloway 2016; Yesner 2001). It is also possible that the technological variability is due to different land-use strategies, indicated by lack of change in toolstone procurement at the Mead Site between components through time (Goebel and Potter 2016). The most robust examination of causes of lithic variability during the Late Pleistocene – Early Holocene suggests that microblades were associated with lowlands, lowlands were the habitats for moose and bison; bifacial technology was associated with uplands/high elevation sites, uplands were habitats for caribou and sheep (Potter 2011). There is a statistically significant relationship between this physiographic correlation in weapon technology and large mammal habitat can be connected with prey choice (Potter 2011). Therefore, a proponents of a seasonal model suggest that assemblage variability is conditioned by hunting based on the physiographic location of seasonally available resources (Potter 2011). In contrast, proponents of a functional model suggest that assemblage variability is based on hunting practice requiring use of a composite points (microblades) as spear tips and bifacial points as dart tips (Potter 2011).

There are signs that the Northern Archaic mobility strategies and subsistence economies replaced earlier Denali complex strategies due to a shift in how the landscape was used and proportions of certain technological forms. There are multiple hypotheses of how/why this may have happened. These hypotheses include: the Denali complex changing into Northern Archaic or abrupt change in technology (Holmes 2011, 2008), or migrations of populations adapted to changing environment (boreal forest), combination of new and existing populations in interior, Alaska, and/or the diffusion of technology without population replacement (Potter 2016; Reuther et al. 2016).

The archaeological sites recovered from the Tangle Lakes region contribute to the understanding of the cultural history of subarctic, Alaska and North America. Sites in the region and specifically the three sites selected for analysis as a part of this project are significant within the scheme of Eastern Beringian cultural chronology (Table 3.2.1). The sites in this study collectively contain cultural components that are associated with the Late Pleistocene and the Denali Complex, the Late Pleistocene – Early Holocene transition with representative transitional artifact assemblages, and the Middle Holocene and the Northern Archaic tradition. This project ultimately addresses how the site components and technological organization in this study fit into the understanding of the technological shift between the Denali Period and the Northern Archaic Period. A description of the site components selected for this study and the assemblage samples is discussed in the following two sections.

Table 3.1 Cultural chronology of the Tangle Lakes region for cultural context of sites included in this study. The dates and table were modified from Holmes (2008) and Vanderhoek (2011).

Time Period (cal yr B.P.)	Techno-Cultural Designation	Tephra	Notes
11,500 – 9,500	Denali Complex		
9,500 - 6,000	Denali Complex		No dated components
6,000 to 1,500	Northern Archaic Complex	Hayes (~3500 B.P.)	
1,500	Athabascan Tradition		
150	Historic Period		

3.9 Tangle Lakes Archaeological District Site Distribution

Over 900 archaeological sites have been recorded to date within the Tangle Lakes region south of the Alaska Range. As described in the Paleoenvironmental section, this region was deglaciated between 13,000 and 14,000 cal yr B.P; however, the environment presumably remained harsh and inhospitable at this time (Schweger 1981). The first signs of human occupation of this area occur approximately 12,000 cal yr B.P.; however, radiocarbon dates suggest that actual colonization of the Tangle Lakes region did not occur for nearly another two millennia (*c.* 10,200 cal yr B.P.) during the Early Holocene (Blong 2016; Dixon 1985; West 1981). As such, this area has the potential to yield valuable information about human lifeways during the Holocene, especially with regards to the shift in technological strategy between the Early and Mid-Holocene, separated by a hiatus in occupation (Potter 2008b).

Historic sites in the region include trails and roads, cabins, camps, mines, mining equipment, and mining-related landscape modification (Vanderhoek 2011). Valdez Creek and Eureka Creek were historic mining destinations, resulting in historic mining-related camps and other sites. Ahtna and Euro-American hunters and trappers built historic cabins and temporary shelters, meat racks, caches, and traps (Vanderhoek 2011). Most Tangle Lakes prehistoric sites are surficial lithic scatters relating to stone tool manufacture (Vanderhoek 2011). Site types outlined by Richard Vanderhoek in his 2011 report include lithic scatters, house and cache pits, lithic sources, hunting (ambush) sites, and campsites. Many sites are identifiable on exposed rock knolls that provide a view of the surrounding area and are also near water sources (Vanderhoek 2011). Other locations in Tangle Lakes where high densities of sites are expected include transportation corridors (prehistoric travel corridors are documented through historic accounts and as native trails on early maps, often occurring on tops of eskers or plateau edges), alpine ice patches (where caribou were hunted in prehistoric times), lithic procurement sites (where high quality toolstone materials could be quarries), and multiple-resource spike camps (seasonal camp that is centrally located among multiple resources) (Vanderhoek 2011).

Several prehistoric sites in the Tangle Lakes have been excavated and a focus of study due to their contribution to the regional chronology. Several sites have absolute dates and distinctive stone tool technology that fall into the broader region's techno-cultural patterns. Other sites have relative dates based off stratigraphic components and the types of tools discovered at the sites. Despite not all the sites having absolute dates, there are other similarities that can be used to identify patterns. For instance XMH-35 is a residential site that has the highest frequency of well-thinned biface documented in the Tangle Lakes Archaeological District (Robinson 2003). There are few other sites in the Tangle Lakes region with well-thinned bifaces. One of these is sites is Whitmore Ridge, others include XMH-51, XMH-52, XMH-83, and XMH-137 (Robinson 2003). The last four sites listed, and XMH-35 are all on elevated glacial landforms on the east side of Upper Long Tangle Lake near the portage area to Landlock Lake (Robinson 2003). This portage area was submerged during the late Pleistocene and Early Holocene but exposed from the Mid-Holocene onward, associated with the Northern Archaic tradition. The portage area provides a relative date for sites to the Mid-Holocene, associated with XMH-35 component 1 and Whitmore Ridge component 2. Whitmore Ridge is on a high ridge of an esker complex near Rock Creek and Butcher's Pond (West et al. 1996). Selected diagnostic sites and the sites used in this study are outlined in the paragraphs below.

Whitmore Ridge contains both an Early Holocene Denali (Component 1) and a Mid-Holocene Northern Archaic component (Component 2) dated to 9953 +/-60 cal yr B.P. and 5143 +/-199 cal yr B.P. respectively (Potter 2008c). The site type at Whitmore Ridge remained the same between the Denali and Northern Archaic components, as a multi-occupational hunting camp where site function was associated with specialized activities. There were differences in technology between the two components as Component 1 contains bifaces and wedged shaped microblade cores with materials called local "argillite, chert, and welded tuff," and Component 2 contains conchoidal blade core technology, bifaces, burins, made of black marine chert (Dixon 1973; West et al. 1996).

The Landmark Gap Trail site only has a Mid-Holocene Northern Archaic component. The most reliable radiocarbon date from the site is 4330 +/-135 cal yr B.P. from a hearth feature labeled Feature 1 (Mobley 1982; Potter 2008c). The site is considered a tool production site and a hunting overlook. However, Feature 1 may have been a single deposition event. Technology at this site mainly consists of bifacial blanks and preforms, lanceolate bifaces, side scrapers, and hammerstones (Gillispie 1992; Mobley 1982).

XMH-35 is a Northern Archaic residential site with two Mid-Holocene components. The older component has a radiocarbon date of 4450 +/-140 cal yr B.P. (Potter 2008c). The younger component is not dated. There is a house feature associated with the radiocarbon date providing evidence for the site being a residential site. The technology within the older dated component consists of characteristic Northern Archaic projectile points such as notched points that are similar to other sites in the Tangle Lakes with "well-thinned bifaces," including Whitmore Ridge, XMH-52, XMH-51, XMH-83, and XMH-137. Lanceolate technology was recovered from the stratigraphically younger non-dated component (Robinson 2002).

The Reger site has one Early Holocene Denali Complex component with no reliable absolute date. The site is considered a single occupation campsite with a hearth. The technology recovered from this site includes wedged-shaped microblade cores, burins, and a few bifaces and unifaces (West et al. 1996).

The Phipps site has one Early Holocene Denali Complex component dated to 10,190 cal yr B.P. (Potter 2008c). The site is considered a single occupation weapon production site. Technology at the site includes wedged shaped microblade cores, burins often made of gray chert, weathered green and tan chert, and yellowish brown sard (West et al. 1996).

Sparks Point has one Early Holocene Denali Complex component with a combined date of 9200 +/-60 through 9060 +/-425 cal yr B.P. (Potter 2008c). The site is also considered a single occupation campsite with a hearth and lithic technology that includes: wedged-shaped microblade cores, burins, lenticular bifaces, larges cores made of weathered and lustrous chert, gray chert, and yellowish brown sard (West et al. 1996).

3.10 Study Site Backgrounds and Sampling

Four components within three different archaeological sites were selected and sampled for this research. These include the Landmark Gap Trail site, Whitmore Ridge C1 and C2, and XMH-35 (Figure 1.1). The significance and the background of these sites outlining why they were chosen is presented below, as well as a discussion about their sampling. Site maps for each site are found in Appendix A.

Landmark Gap Trail Site Background and Sample

The Landmark Gap Trail site (AHRS referenced as XMH-289) is the closest of the three sites to a known lithic toolstone source analyzed in this project. It is approximately 1.4 miles southwest of the Landmark Gap Quarry (Figure 1.1). This site was first investigated in 1976 by Zinck and Zinck, and then excavated in 1981 by Charles M. Mobley and Morris. The site was later re-excavated by Thomas Gillispie in 1991, and then again most recently, by the Alaska State Office of History and Archaeology in 2004. The site is located on a heavily used ATV and foot trail running north from mile 24.6 of the Denali Highway to Landmark Gap Lake. Around mile 1.5 of the Landmark Gap trail begins a drumlin with approximately 62 meters of lithic artifacts. The drumlin results in a north-south trending 12-meter-high knoll 200 meters west of Rock Creek, which is the outlet stream of Landmark Gap Lake. It is less than a mile from Landmark Gap Lake and is part of a low glacial landform made of gravel and silty sand. The site on this knoll has an optimal viewshed to the north and south, and as far as the mountain ridge walls to the east and west. The site has been disturbed by the construction and use of the ATV trail. There are artifacts located on the surface of the trail. Vegetation cover over the rest of the site off the trail includes, dwarf birch, willow, moss and lichen, and blueberry bushes.

The Landmark Gap Trail Site contains artifacts that have an uncalibrated date range between 3,728 +/-79 years ago and the Oshetna Tephra (5,700 years ago) (Gillispie 1992). The soil deposition consists of eolian silt, an Oshetna-like tephra, a paleosol yielding a 3,728 +/- 79 years ago (4098 +/-117 cal yr B.P.), Jarvis Creek Ash tephra, and organics (Appendix A). Based on the 1991 excavation there is cultural material throughout each horizon; however, a large portion of the material (n= 21,447 flakes and tools) occur in the B-Horizon. This comprises sediment 5 (S5), which dates between the 3,728 +/-79 years ago (4098 +/-117 cal yr B.P.) and the estimated age of 5,700 B.P. (5573-4654 cal yr B.P.; Potter 2008c) for the Oshetna Tephra deposition (Gillispie 1992). The 1991 excavation reaffirms the dates that encompass the cultural components at XMH-289. However, according to Mobley (1982) and personal communication with Tom Gillispie (February 26, 2018) the most securely dated lithic assemblage was collected and documented by Mobley (1982) in association with Feature 1. Feature 1, excavated in 1982 by Mobley, is described as a dish-shaped depression at the bottom of which contained gray soil and dense concentration of artifacts understood as “definitely cultural,” found in Appendix A (Mobley 1982:89). This feature maintains stratigraphic and chronological control better than the later excavations. As seen in the site maps in Appendix A, Tom Gillispie noted that many of the other excavation units were disturbed due to the presence of the ATV trail and the relatively shallow deposition of soil resulted in poor stratigraphic control (Mobley 1982). Therefore, the following discussion of the site and sample is based on Mobley’s (1982) excavation.

The stratigraphic profile recorded by Mobley (1982) displayed in Appendix A includes 20-30cm of surface vegetation, which includes alpine tundra shrubs and mosses; followed by Level 1, average of 10 cm of loose dark brown silty loam formed from loess and decomposed organic material; below is a tundra fire carbon streak described as a thin lamina of carbonaceous soil composed on 1mm diameter charred roots; volcanic ash is the subsequent layer noted as the albic horizon in Level II up to 2cm thick; Level II is a sequence of compacted grayish brown and dark reddish loam varying between 15-30 cm thick; finally, Level III consists of mottled dark grayish brown and dark yellow brown gravelly loam (glacial till), containing gravel, cobbles, and boulders (Mobley 1982). Feature 1 is situated within Level II, which is comparable to Gillispie (1992) B-horizon (S5), mainly within unit 098N/100E and partially within 098N/099E. The lens of carbonaceous soil is directly above Feature I artifact providing the younger book-end date for the assemblage. Feature I is an isolated grouping of artifacts that was discrete from the surrounding excavated area, such that the artifacts were packed so tightly the artifacts in Feature I can be interpreted as a single event that is associated with radiocarbon date of 4330+/-125 years ago (5309-4533 cal yr B.P.). obtained from within the feature (Potter 2008c; Mobley 1982). The debitage that was collected from other excavation units during the 1982 excavation and subsequent excavations cannot be absolutely associated with a firm date such as the lithics in Feature 1 (Appendix A). The other lithics are best relatively dated based on stratigraphic association with ash fall and cannot be limited to isolated lithic use events.

The Landmark Gap Trail site has been interpreted as a tool manufacture and large game lookout site. Evidence for this interpretation is based on several factors: the debitage to tool ratio, proximity to the Landmark Gap toolstone source, and the few tool forms that exist at the site (Mobley 1982). Based on the 1982 excavation, the tool to debitage ratio is low (1:234). The tools that do exist are mainly bifacial and only one seems to be functionally specialized, the others reflect minimal to no maintenance activity (Mobley 1982). There were no tools that suggest site specialization towards hunting or meat processing, as no projectile points were recovered (Mobley 1982). However, the site is not interpreted as only a tool production site because it is not immediately adjacent to the toolstone source, it is approximately 3km south of the quarry site. Additionally, the Landmark Gap area is a current moose range, and caribou continue to move from the north through Landmark Gap (Mobley 1982). The site also provides a better vantage point than other locations in the area (Mobley 1982). Therefore, the site could have a multipurpose function, allowing for tool manufacture of nearby high quality toolstone, while also watching out for game. However, the presence of Feature 1 and interpreted two burning events suggests some energy was put into the layout of the camp. Additionally, the discrete horizontal nature of the lithic assemblage within the hearth may be an isolated event where the tool manufacturer or manufacturers disposed of the lithic production debris within the hearth (Mobley 1982). One could argue that a sample of an isolated production event is not representative of the site as a whole. However, due to the nature of the site it was determined that a lithic sample associated with an absolute date is preferable to a relatively dated sample lacking good stratigraphic control, despite being a discrete event. Mobley (1982) hypothesizes that local fine-grained material is from Landmark Gap, but also mentions the variable weathering and patination of the artifacts that he refers to as local material. Mobley (1982) attributes the variation in patination to differential weathering, timing of deposition, differences in soil matrices, or local variations in material.

Mobley (1982) argues that significance of Landmark Gap Trail Site within the regional chronology is its association with West's (1974) Amphitheater Mountain Complex. Mobley (1982) argues that Landmark Gap Trail Site's association with the Amphitheater Mountain Complex provides evidence that this is not a distinct cultural chronological complex, but rather a result of functional activity specialization of Tangle Lakes regional patterns. Additionally, more evidence calling to question the validity of the Amphitheater Mountain Complex is the based-on ambiguities in type descriptions and justifications, and that while the Amphitheater Mountain Complex has been argued as an earlier typological complex than the Denali Complex with an uncalibrated ago estimate between 8000-10,000 years ago (Mobley 1982). Yet, the Landmark Gap Trail Site Assemblage matches the Amphitheater Mountain Complex forms but dates to 4330+/-125 B.P. (5309-4533 cal yr B.P.). The date of the site is similar to that of XMH-35 which yielded notched points in the date range of 5573-4654 cal yr B.P. (Potter 2008c); however, the Landmark Gap Trail Site assemblage is not similar to that of XMH-35. Therefore, the examination of the two relatively contemporaneous sites will provide further data and interpretation on the question of the functional activity specialization of the Landmark Gap Trail Site.

Based on the 1991 excavation Gillispie (1992) confirms that the main occupation of the site could be relatively dated between the uncalibrated date range between 3,700 and 5,700 years ago and recognizes its temporal association with XMH-35. Gillispie (1992) argues based on Mobley (1982) interpretations and the parallels between Landmark Gap Trail Site and XMH-35, that Landmark Gap Trail Site can be placed within the Northern Archaic Tradition chronological sequence. Due to the poor stratigraphic integrity throughout the Landmark Gap Trail Site it is difficult to determine the presence of multiple occupations or movement of artifacts from the definitive occupation level by post-depositional disturbance processes (Gillispie 1992). The 1991 excavation provided more information on site function, such that it yielded 16 bifacial preforms, seven lanceolate bifaces, six side scrapers, a hammerstone and a biface fragment (Gillispie 1992). This suggests that isolated activities may have occurred at the site, mainly being that of biface manufacture, but also weapon and composite tool repair, and meat or hide processing (Gillispie 1992).

Whitmore Ridge Background and Samples

Whitmore Ridge is a significant site in the Tangle Lakes regional chronology because it contains occupational components ranging between 10,630 +/-60 years ago (12,612 cal yr B.P.) and 3800 +/-180 years ago (4196 +/-244 cal yr B.P.) (West et al. 1996), thus it includes archaeological data that encompasses the changing paleoenvironment and technological trends through time (Appendix A).

The Whitmore Ridge Site is located on a north-trending esker ridge that has a 360-degree view, looking out over Rock Creek to the south. It is also approximately 600m west of Butcher's pond and about 3km from the base of the Amphitheater Mountains. These mountains could be a primary source of toolstone, and erosion into nearby creeks could provide secondary sources (West et al. 1996). Due to the site's location, soil deposition is shallow, amounting to a depth of only 30 cm above bedrock.

Most of the collected artifacts were located within the buried soils. There are two buried soils at the maximum extent of deposition at the site; however, there are a number of locations where the both soils are not present due to the high winds in the area (West et al. 1996). The summarizing profile units for Whitmore Ridge as published in West et al. (1996) from surface to bedrock include the O horizon; Buried Soil – Loess 2 encompassing A1, A2, B, and A1b; Buried Soil – Loess 1 encompassing A2b and Bb; and fluvial sands and gravels – C horizon . Loess 1 sediments have two series of bracketing dates that range from the Late Pleistocene/Early Holocene transition through the mid-Holocene. The sediments associated with the published stratigraphic units were described by Brian Robinson in unpublished field notes. Robinson's descriptions are as follows for the cultural component layers: B-Horizon is represented by "red to tan (5/4 7.5 YR) mottled silt and fine sand, some charcoal smears and flecks. Going downslope off the ridge crest, the red color gives way to a dark brown (2/1 5Y) as charcoal becomes more abundant. This darker unit is designated B1. In some places a dark gray subunit can also be recognized, this is designated as B2." "Units A and B, B1 and B2 represent a paleosol, a weak podzol, subunit B2 represents soil horizon A2. The red color (unit B) indicates burning, possibly a natural burn; charcoal washing down slope changed the color to a black band representing the A1 horizon of the paleosol." "The greatest abundance of cultural material comes from these two units, A and B" (Robinson 1978).

Artifact concentrations were discovered over approximately 40m of the site, thus this area considered to have occupational distinct loci (activity areas/lithic concentrations) have been excavated at this site. Loci 1 and 3 are interpreted as Early Holocene - Denali Complex, which contained cultural material in the lowest Loess 1 level (component 1) (Appendix A). Locus 2 is the only area associated with Component 2, which is the A2b soil horizon, dating between 3800+/- 180 and 5480+/-300 B.P. (6942-5603 cal yr B.P.; Potter 2008c), (Appendix A). It is interpreted as a 'transitional assemblage showing similarities to the Denali Complex forms,' (West et al. 1996) but also the technology is compared to Northern Archaic tool forms at XMH-35 (Robinson 2003).

A debitage sample of 396 flakes has been analyzed from Locus 2, Component 2. Loci 1 and 2, as seen in site maps in Appendix A, are both considered short-term activities with patterned specialization towards core and blade technologies (West et al. 1996). Locus 1 is speculated to be temporally associated with Locus 3; however, Locus 1 is interpreted as a specific short-term activity. While, Locus 3 also is technologically distinct, it is highly concentrated with debitage made of local "argillite" or "chert" that is likely material from one of the quarries of interest (West et al. 1996). Locus 3 also shows signs of bifacial thinning activities due the representation of large bifacial thinning flakes (West et al. 1996). A sample was selected from Locus 3 to represent component 1, because Locus 3 is directly associated with a 10,270 +/-70 B.P. date (11,603-11,249 cal yr B.P.; Potter 2008c). Though Loci 1 and 3 are temporally associated, Locus 1 is not associated directly with an absolute date and it represent as specific activity that may not be associated with the rest of the component. Further, the interpretation of Locus 1 as a temporally distinct occupation from Locus 2 is not fully confirmed, the two lithic concentrations could be different activities performed by the same site inhabitants over a short period of time. Due to the ambiguity surrounding the temporal-occupational significance of Locus 1 it was not included in the sample to represent Component 1. It is important to note for transparency that the artifact accession catalog for Whitmore Ridge and the documented site maps are not clearly described and are the result of multiple excavations from multiple years and site mapping strategy is not described. Locus 3 is clearly marked on site maps as the "69 Block" of the excavation. In the accession catalog the only Locus 3 accession numbers are associated with "69 Block:C" (Appendix A). The number of artifacts contained in bags labeled "69 Block:C" reflect the description of Locus 3 and the size of the excavation area. However, on a second map there is an excavation unit labeled "69:C?" that is not associated with the main 69 Block which is clearly labeled as Locus 3. It is likely that the question mark associated with the labeling of an unknown excavation unit as "69:C?" is not valid, and not accepted as the location of Locus 3.

<u>XMH-35 Residential Site Background and Sample</u>

XMH-35, characterized by a residential feature and Northern Archaic notched point technology. The site is believed to have been occupied intensively for a short period between 4500 and 4200 B.P. (Robinson 2003). XMH-35 is located on the east side of Upper Long Tangle Lake and is situated on a sharp knoll with a westward view. It is north of the portage area between Landlock Lake and Upper Long Tangle Lake that was submerged during the early Holocene. There is only approximately 20 square meters of flat space at the top of the knoll, which was excavated (Robinson 2003). The site was investigated four times over the course of five years. It was first excavated in 1964 by West, Reger, and Pitts, then again in 1967 by West and Reger opening up units A2 and A3, and B2 and B3, and began excavation of C2, C3, A4, and B4 (Appendix A). A trench was later excavated in 1968 by C. Flint and E. Peterson to follow the double soil horizon along the ridge. Ultimately, excavations were concluded in 1970 by West, Reger, G. Dixon, J. Hamilton, B. Hamlin, Mike MacDonald, and possibly R. Farrell.

The site is referred to as a house feature based on the identification of a hearth containing charcoal bone meal and grease within excavation units A2, A3, B2, and B3. Additionally, two post holes were identified in the NW quadrant of unit A2, and the SW quadrant of D5. The final determination of the size of the house was 4m north-south by 3m east-west (Robinson 2003). Much focus for dating and understanding the placement of this site in regional cultural-historic chronology is based on the presence of distinctive notched points. Notably, similar points have been discovered at Palisades II, components 6 and 5 of Onion Portage, and Yuktu complex in Anaktuvik Pass (Robinson 2003).

The site has two cultural occupation components, based on stratigraphic integrity found in the house feature. The upper component is dominated by a uniform style of lanceolate points, whereas the lower component is dominated by Northern Archaic projectiles. The 20 m^2 excavation area in the house feature contained about half of the recovered artifacts. The upper cultural component (first 0-10 cm) is dated relatively based on the presence of eight lanceolate and three notched points. The lower component in the house feature has been radiocarbon dated to 4450 +/- 150 B.P. and 3445 +/-115 B.P. (5573-4654 cal yr B.P.; Potter 2008c) and the dominant artifact forms are notched points in contrast to lanceolate points, as outlined in Appendix A (Robinson 2003). Both artifact types are characteristic of the Northern Archaic tradition.

The sample for this site was chosen from Level III. Robinson (2003) analyzed the stratigraphic designations from the two excavations at XMH-35 that took place in 1967 and in 1970. This required understanding the cultural component units within in terms of the stratigraphic sediment and color descriptions that occurred at different locations of the site. The stratigraphic information was consolidated into four encompassing levels, that first prioritized numeric depths and then sediment color descriptions (Appendix A). The first 10cm of sediment could be assigned to level 1, and 12-15cm was securely assigned to level 2. However, the first 10-20cm was likely associated with level 1 and 2 but there could have been some mixing with level three. Therefore, levels 1 and 2 are considered the upper component and were not of interest to be included in the sample for this project. Levels 3 and 4 are associated with the lower component which is of interest for this project. As mentioned above, stratigraphic depths up to 20cmbs could be a mixture of level 2 and 3, so level 3 sample selection excluded lithics that had a depth at 20cmbs or less despite the color description. The sample was only selected from level 3 sediments from inside the house because it is directly associated with radiocarbon dates and is clearly recorded across the site, inside the house, from both excavations (Robinson 2003).

While level 4 is also considered part of the lower component, it may be an isolated deposit- midden, which was not recorded as continuous or in both excavations. The ambiguous status of the level 4 sediments warranted its exclusion from the sample. Level 3 outside of the house was sampled because it was neither directly associated with a date nor continues the clear stratigraphic units of the feature. Units B3, B4, and A3 were sampled because the stratigraphic integrity was best in these units within the house feature and were drawn.

Chapter 4: Analytical Methods and Materials

4.1 Introduction to Methods

This chapter describes the methods used to analyze the lithic materials from the samples taken from the sites described in Chapter 3. The lithic random samples from debitage assemblages from Denali Period Whitmore Ridge Component 1, and Northern Archaic Period Whitmore Ridge Component 2, Landmark Gap Trail Site, and XMH-35, are the basis for establishing chemical and behavioral lines of evidence for addressing the research questions. This chapter begins by discussing the methods for random sampling the component assemblages. Next, the techniques established for sourcing the lithic materials that were sampled from the components will be discussed. This involves describing the sampling strategy of bedrock quarry material from the Landmark Gap and the Long Tangle Lake Quarries, and then discussion of best practice chemical analytical procedures for establishing accurate elemental signatures of each quarry that can be used to assign artifacts. Finally, the methods for analyzing the lithic attributes are described in order to combine behavioral data with the spatial sourcing and raw material type data.

4.2 Archaeological Assemblage Sampling

Three archaeological sites were chosen in addition to the two quarry locations, to evaluate the lithic assemblages in terms of raw material distribution (Figure 3.1). The three sites are located at varying distances from the two quarries and have distinctive temporal components relevant to understanding transitions in human mobility strategies in the Tangle Lakes region through time. The Landmark Gap Trail Site is the closest of the three sites to a known prehistoric quarry. It is approximately 1.4 miles southwest of XMH-389, the Landmark Gap Quarry site (Gillispie 1992). Whitmore Ridge site is located approximately six miles southeast of Landmark Gap Trail site.

Analysis of archaeological material culture from these three sites was limited to lithic technology, specifically debitage. Analyses on the lithic debitage included IFA analysis (Andrefsky 2005; Prentiss 2001) and chemical analysis of artifacts of the appropriate dimensions. Due to the large quantities of lithic debitage recovered from each of these sites, samples were selected from each site component relevant to the study. Microdebitage (debitage that is less than 1mm in maximum linear dimension (Andrefsky 2005) was excluded from both the lithic and chemical analysis. A random sample of lithic debitage was chosen from each site for complete lithic analysis and then subsampled based on appropriate size and dimension for the chemical analysis. To be included in the chemical analysis the lithic was required to have a flat surface, with no cortex that covered the x-ray opening on the non-destructive Niton ED-pXRF.

The largest analytical unit (sample number) for lithic analysis is 396 flakes, the total number of lithic debitage from Whitmore Ridge Component 2. A sample of 400 was designated as the largest analytical sample in the study. Therefore, 1,597 pieces of lithic debitage were included in the lithic analysis from all four site components from the three sites. The samples from XMH-35, Landmark Gap Trail Site, and Whitmore Ridge component 1 were randomly selected. The sample from Whitmore Ridge Component 2 was the total number of lithic debitage in the component assemblage. The samples were randomized by using a four chambered random sample sorter (Appendix B). At XMH-35, Landmark Gap Site, and Whitmore Ridge component 1, artifacts were collected in bags from excavation units with labels ranging from a single artifact per bag to over 500 flakes per bag (often referred to as a flake lot bag). Each sample was randomly selected using a random number generator in excel. The samples were randomly selected from each component stratified by number of lithics in each bag, and each spatial organizational unit given from each site. Therefore, the random sample would proportionally represent artifacts in each bag. In some instances, a sample of 400 was chosen from an entire component because that was the most specific provenience that was recorded. However, from other sites, such as XMH-35 there were more specific spatial provenience notes such that the stratified random sample of 400 was divided up between multiple spatial units (excavation units). In this case, the system for choosing a stratified random sample described above was applied to each spatial unit but selecting a proportional number of artifacts of the total 400 associated with the number of artifacts in each spatial unit.

The lithic debitage that were sampled from these components are only associated with provenience of final deposition until chemically sourced. When the source location is established for the material in the site assemblages, then the lithic debitage may be spatially linked to its point of origin and point of discard. This allows for interpretations about transport of the lithics and mobility patterns associated with material transport. In order to obtain material source data, the bedrock from two primary source quarries were analyzed chemically. The Landmark Gap Quarry and the Long Tangle Lake Quarry are hypothesized to have contributed the majority of materials to Tangle Lake Archaeological

District lithic assemblages. Therefore, if distinct chemical signatures can be established for each quarry, the majority of lithics from each assemblage sample can be given an accurate point of origin.

4.3 Quarry Sampling Strategies

The Landmark Gap Quarry was initially mapped and excavated by Fred West in 1973. The designation of this site as a prehistoric quarry was also accepted by geologists as mentioned in Stout's (1976) geological report of the region. The second quarry is the Long Tangle Lake Quarry, east of Long Tangle Lake and about 6 linear kilometers northeast of Landmark Gap Quarry but separated by a mountain ridge. Long Tangle Lake Quarry was established as a toolstone source based on the increasing density of surficial sites leading to the high quality toolstone (Richard VanderHoek, personal communication 2017). Both sites were accepted as quarries because of the high quantities of waste flakes, and tested and chipped nodules at the quarry locations (Vanderhoek 2011). The purpose of sampling material from these two quarries was to gather raw material samples used in the chemical sourcing study to distinguish local Tangle Lakes material from non-local material, as well as to distinguish Landmark Gap and Long Tangle Lake toolstone material from each other and other common toolstone material found in Tangle Lakes lithic assemblages.

According to Malyk-Selivanova et al. (1998), appropriate collection methods for chemical analysis of prehistoric raw material sources requires at least 15 samples to be collected from each horizontal layer or chain of nodules of the quarry outcrop. Collecting this many samples makes it likely that the samples span the variability of the compositions of the outcrops. Outcrops' compositions vary between beds. During fieldwork, 20 – 30 samples were collected from each horizontal layer or exposed nodule from each quarry to ensure statistical significance for chemical analysis (Figure 4.1, Table 4.1). It is critical that all samples that are measured to characterize the material from the two quarries were taken directly from the bedrock; as loose rock samples may have been deposited at the quarry through glacial, water, or human activity.

The Long Lake Quarry is located directly adjacent to a clear alpine river, where some toolstone quality bedrock beds extend into the river (Figure 4.2). The formation is characterized by downhill sloping stepped rock beds with rocks that tend to break into cubes (Figure 4.2). A total of 21 different localities were sampled directly from the bedrock at the Long Tangle Lake Quarry, with at least 20 samples from each locality. Eighteen different localities were sampled from the bedrock of the Landmark Gap Quarry with at least 20 samples from each locality.

The Landmark Gap formation is characterized by exposed bedrock outcrops on an alpine tundra covered knoll (Figure 4.3). In order to increase the likelihood of capturing the chemical variability of the exposures, 20 samples were collected from both the upper and lower portion of the exposure. There is enough material collected from each locality to make at least 30 samples. Surficial lithic assemblages consisting of lithic debitage were located on unvegetated areas on knolls and glacial eskers surrounding the quarries. Chipping was noted on the raw bedrock at the quarries. Eleven surficial lithic assemblages were documented during informal survey while navigating to the quarries. Lithics from the sites directly adjacent to the quarries were collected for WD-XRF analysis to compare directly to the bedrock samples. Sixteen surficial artifacts from the new sites located closest to the quarries (XMH-01562, XMH-01563, XMH-01564, XMH-01565, XMH-01566) were collected, photographed in situ, and described. The limited number of artifacts that were collected are likely to be representative of the material at the quarries (Table 4.1). The artifacts that were collected were chemically analyzed as a comparative artifact sample to the bedrock samples collected from the quarries. The reasons for the selection of particular artifacts for collection were the sites' proximity to the quarry source, the artifacts appeared visually similar to the bedrock quarry material, the artifacts sizes are amenable to chemical analysis, and the artifacts selected were visually representative of the material variability of the lithic scatters. The artifacts that were collected have been measured, weighed, photographed, and 3-D scanned in the museum lab, and analyzed with the wavelength-dispersive XRF spectrometer. The field work resulted in the collection of 1,225 bedrock quarry samples, and 16 artifacts and 1 site associated rock sample which will all be housed at the University of Alaska Museum and available for future research.

Table 4.1 Chemical sourcing samples obtained during 2017 fieldwork.

Site	N artifacts collected	N bedrock samples collected
XMH-1562	2	0
XMH-1563	1	1
XMH-1564	1	0
XMH-1565	10	0
XMH-1566	2	0
XMH-1392	0	653
XMH-398	0	572

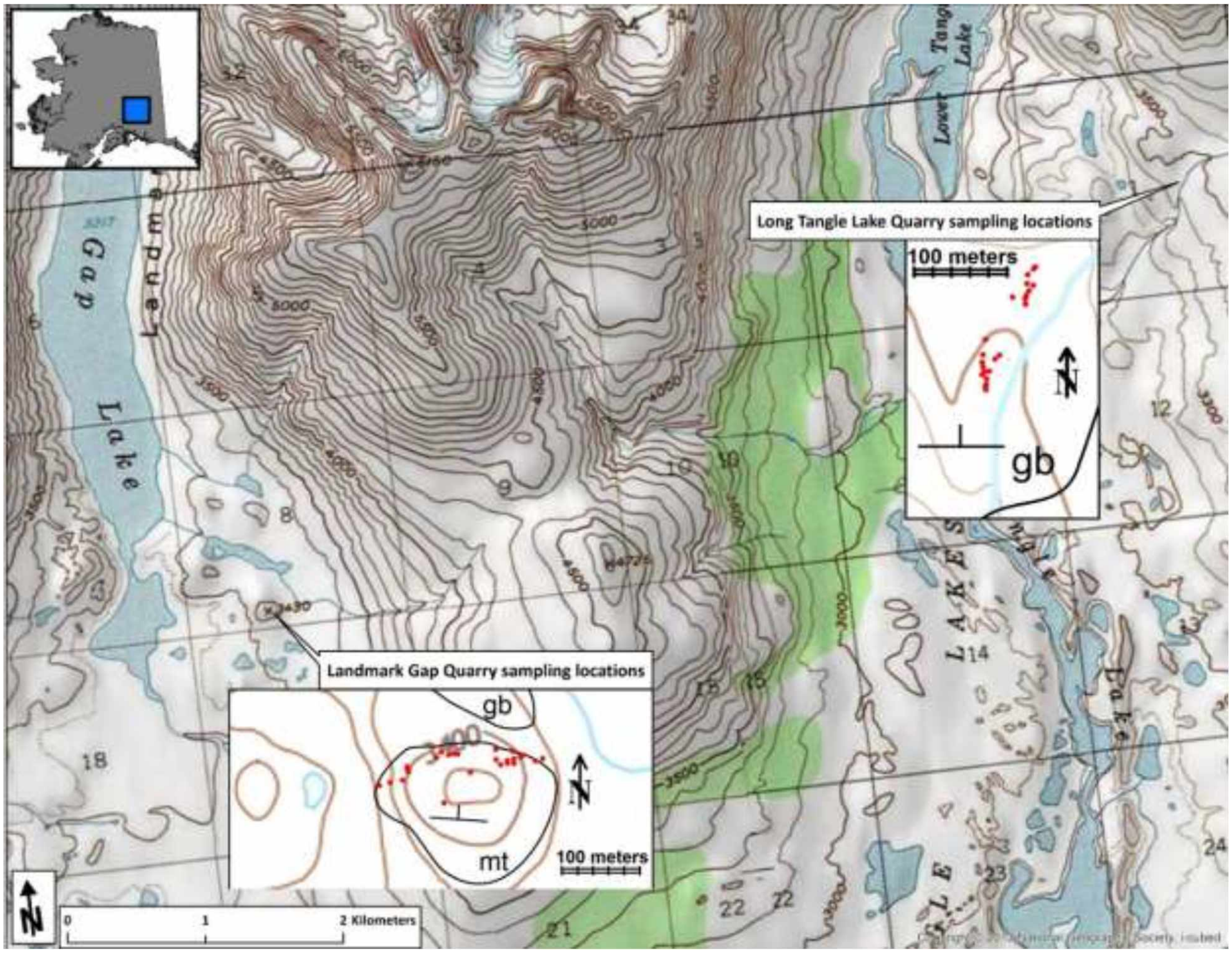

Figure 4. 1 Sampling locations of bedrock at each quarry. The call out boxes show the sampling locations at each quarry in detail, on top of a topographic map of the area between the two quarries.

Figure 4.2 Geological formation at the Long Tangle Lake Quarry. The photo on the left is looking north at a close up of some of the rock beds, and the photo on the right is looking south demonstrating the quarry’s proximity to the creek.

Figure 4.3 Landmark Gap Quarry geological formation. The photo looking south at north side of the formation which is a mostly vegetated knoll with exposed bedrock outcrops.

4.4 Chemical Analysis

X-ray fluorescence spectrometry (XRF) is an analytical technique that is employed to identify the chemical composition of artifacts. Archaeologists often are interested in the chemical composition of artifacts because it relates to the origin of artifacts' material. The practice of determining the origin of a material to answer archaeological questions relating to procurement is referred to as artifact sourcing or artifact provenience studies. Quantitative chemical techniques are necessary to source artifacts when the source cannot be identified based on visual characteristics of the material. The ability to visually identify an artifact's source with certainty is often unreliable.

In this study, methods were established for using X-ray fluorescence spectrometry to define bedrock from quarries in the Tangle Lakes Archaeological District. Next, distinct chemical signatures were statistically defined for each quarry. This provides a precise and accurate chemical sourcing technique for local "common toolstone" that occurs in lithic assemblages in the Tangle Lakes. "Local" is defined as within the boundaries of the Tangle Lakes Archaeological District, and "common toolstone" is defined as the material that makes up large amounts of lithic assemblages, but its geological definition has been previously undefined through visual identification. Chemical methods are necessary for distinguishing the sources of the "common toolstone" in this study, because visual qualitative sourcing is not accurate for this material. The weathered surfaces of artifacts and bedrock are highly variable in color. Additionally, the cross sections of the two bedrock quarry materials have tremendous visual overlap. The approach outlined in the methods involves chemically analyzing unknown bedrock from quarries with known archaeological significance. A destructive wavelength-dispersive XRF has the greatest accuracy and precision with which to establish the elements that are necessary for distinguishing each material and defining chemical signatures of the two quarries. Using this information an analytical routing was developed to analyze artifacts non-destructively on an energy-dispersive pXRF, which is limited to measuring a narrow range of elements.

4.5 Distinguishing Tangle Lakes Toolstone

As stated above this project addresses a problem with the analytical method of sourcing non-igneous, *unknown* fine-grained silicate toolstone that makes up a large portions of archaeological assemblages in the Tangle Lakes Region. Due to the existence of two archaeological quarries consisting of high-quality bedrock, it is possible to use destructive WD-XRF technology to define the bedrock quarry materials that previously were geologically undefined, subsequently accurate and precise distinct chemical signatures can be established for each quarry. Appropriate methods for sampling from the bedrock of the quarries, sampling for chemical analysis, and operation of the WD-XRF spectrometer is essential for establishing reliable results for ultimately matching artifacts to the quarries. The following section outlines the methods chronologically from field sampling to XRF operation to establish a *best-practice* routine for future sourcing studies of "common toolstone." Furthermore, the routine developed in this study will be available for regional, Alaskan archaeologists to analyze artifacts from their assemblages to learn if material was traveling outside of the Tangle Lakes region.

4.6 WD-XRF Identification of Quarry Toolstone

Following the collection of the bedrock quarry samples and associated artifacts a subsample was chosen for chemical analysis. The budget for WD-XRF analysis allowed for 54 hours of analysis with the spectrometer. A single sample requires approximately 20 minutes of analysis time. Ultimately, 165 samples consisting of bedrock samples from the two quarries, non-toolstone outgroup bedrock from the area around the quarries, and artifacts from the immediate vicinity of the two quarries were analyzed with the WD-XRF. Stratified sampling was employed to select bedrock samples from the original sampling localities from each quarry. Material from each sampling locality within each quarry was ranked as high, medium, or low quality. Six samples were analyzed from high and medium quality toolstone sampling localities, and two samples were measured from poor quality toolstone sampling localities.

The flat cross-sections of 157 quarry samples (68 samples from Landmark Gap Quarry and 89 samples from Long Tangle Lake Quarry) were analyzed on the WD-XRF spectrometer. Each sample was cut to expose an internal flat surface of the rock, which was cut to fit a 37mm sampling cup. The surface of each sample was ground smooth using a diamond wheel. The WD-XRF is sensitive to surface irregularities. The analysis surface of the samples for the WD-XRF was 37mm capturing the maximum variation in each sample per analysis. The analysis was performed using PANalytical Omnian software analysis, which was previously standardized with artificial standards and checked with international standards. This analytical routine is the most accurate and flexible when analyzing unknown material (PANalytical 2018). It allows the greatest accuracy and precision of net element intensities and gives a comprehensive picture and quantification of all elements detected (PANalytical 2018).

The information is accessible to editing and review to ensure all the necessary spectra peaks are accounted for (PANalytical 2018). No special calibration was created for the quarry samples prior to analysis because the type of rock was unknown, thus ensuring that each element possibly represented in the sample was measured with each analysis. By not creating a calibration prior to the analysis of the material, the procedure requires an extra review of the spectra produced, by means of manually identifying elemental K, L, and M alpha and beta peaks not marked by the software. This also eliminates the "black-box" aspect of the analytical software's capability. Corrections included removing rhodium (Rh) peaks from inclusion in the analysis, because presence of Rh in the results is caused by background noise of the Rh tube of the x-ray spectrometer. Additional, edits involved identifying unlabeled Rb, Sr, Y, Nb, and occasionally Mo K-alpha peaks and K-beta peaks. Cr and V peaks often needed to be identified and labeled as well. Manual identification of peaks is reliable because peaks represent the irradiation of electrons for elements at specific energies. If an element is present in a sample, a peak will be identifiable at the appropriate energy associated with the energy that is released after electrons have been irradiated and fallen back down to the original level in the electron cloud. The height of the peak is associated with the amount of the element present in the sample. The wavelength-dispersive XRF measured every element that was present in each sample with the greatest accuracy and precision using X-ray fluorescence spectrometry of non-fused bead samples.

All final raw count measurements were converted to weight percent and ppm after all the peaks were manually edited and accounted for in the PANalytical program. The WD-XRF automatically calculates the Bragg's Angle based off of known angles of incidence on a flat surface which is what makes the results sensitive to surface irregularities, as irregularities of the analytical surface will affect the angle of scattering such that the angle of incidence and the angle of scattering will not be equal. Likewise, the WD-XRF Omnian software also accounts for Bremsstrahlung radiation (background radiation) and allows the analyst to manually adjust the assigned peaks based on visual analysis of the Compton peaks.

Therefore, chemical trends in the samples from each quarry could be directly compared for each element, so if samples from one quarry have higher silicon dioxide ($SiO2$), then it is accurate to say that the material from one quarry is higher in $SiO2$. The elemental concentrations of all samples from each quarry were compared based on trends within each quarry of each element.

Capturing all possible element concentration in the two quarries' bedrock material with the greatest precision and accuracy allows for determination of the geological definition of the material in question, and subsequently, reliable comparison of the chemical concentrations of the two quarries. Thus, the elements that are important for distinguishing the two quarries can be identified in the artifacts as well. Artifacts that have similar concentrations to those important distinguishing elements of the quarries and can be assigned to the quarries using appropriate statistical measures for establishing significant assignments. However, the first goal of WD-XRF analysis of the quarry bedrock was to determine the type of material at each quarry and if the two quarry materials could be distinguished chemically.

Methods for determining the type of rock present at each quarry had several steps: (1) The first involved visually examining each sample cross section with a hand lens and microscope to identify the grain size and shape, how the grains are welded together, and any particular diagnostic features such as pyrite inclusions. (2) Chemical analysis of non-toolstone quality bedrock on the same formations as the quarries was employed to test for similarity to known igneous rock types (Figure 5.1.4). The compositions of the intruding poor-quality bedrock among the toolstone quality material at each quarry is representative of the geological maps of the Tangle Lakes area. (3) Finally, the chemical analysis on the quarry toolstone material resulted in high concentrations of certain elements which allows for identification of parent materials for each quarry (presented in the results section). Metamorphism of the parent material was hypothesized based on evidence from steps 1-3 (presented in the results section). To further test for metamorphosis of the parent materials at each quarry with high calcium were tested for calcite. High calcium concentrations without the presence of calcite indicates CO2 driven off when the material was heated during metamorphosis. Further, the shape of pyrite inclusions (occurring in both quarries) can be visually analyzed to indicate metamorphosis, such that pyrite appears in cubic form from recrystallization of the parent material during metamorphism.

4.7 ED-XRF Calibration for Non-destructive Analysis

A non-destructive ED-pXRF is a different analytical tool than a WD-XRF. XRF spectrometers incorporate X-ray energy to irradiate electrons of elements within an analyte, and the results must be calibrated properly to compare the values. However, the ED-pXRF separates the emitted X-rays based on their energies, but WD-XRF separates X-rays based on their wavelength. A calibration of results collected on both devices ensures that element values are of reasonable accuracy. The non-destructive ED-pXRF detection capabilities are more limited than the WD-XRF, such that the ED-pXRF used in this study can only detect elements with atomic numbers from sulfur (S) through uranium (U). This eliminates the ability to use sodium (Na), magnesium (Mg), aluminum (Al), and silicon (Si), which are often present in rocks, and Si is a major element in the concentration of the quarry materials for this project based on the WD-XRF analysis. However, because artifacts can only be analyzed on the non-destructive ED-pXRF, the quarry groupings and artifact assignments can only be based on the elements detected with the Niton pXRF. Therefore, in comparing the accuracy and precision of the ED-pXRF in terms of the "true" standard and WD-XRF values the elements that are identified in the samples by both devices can be used to compare the devices.

First, there are multiple brands of pXRF spectrometers. They have different precision and accuracy for certain elements based on their hardware. The Bruker ED-pXRF has often been marketed to archaeologists, whereas Niton ED-pXRF devices tend to be marketed towards geologists. Archaeologists may argue that Bruker pXRF devices are the most appropriate for replicable archaeological work based on the accessibility of Bruker pXRF devices to archaeologists. However, the value of a more accurate measurement acquired for a given material from an analytical tool should be priority. As such, in the context of this project the Thermoscientific Niton XL3t XRF analyzer, high-performance semiconductor, equipped with an AU anode and helium purge, 50KeV and 200µA x-ray tube was capable of providing fully calibrated concentration values of elements that fit the linear regression of elemental values of international standards for more elements than could the Bruker Tracer III-V portable XRF analyzer with a rhodium, tube and a SiPIN detector with a resolution of ca. 170 eV FHWM for 5.9 KeV X-rays (at 1000 counts per second) in an area of 7 mm^2 . The Niton has a general calibration for various elements in rocks. The Niton applies its calibrations of the elements to the x-ray data collected, yielding concentrations. The Bruker pXRF does not use a built-in calibration for materials, so a calibration would have to be created to measure elemental concentrations for the samples in this project, because raw counts are not directly related to concentrations. Though built in calibrations can be problematic when used as a "black-box" to produce data without understanding how it is produced, the Niton data was evaluated to ensure comparability to the WD-XRF data.

First, nine homogeneous standards, including flat glass, albite-1, anorthite, quartz, BHQ3, diop1, Dunite-1, 1703, and Barite were analyzed on the Bruker Tracer III-V portable XRF analyzer jointly used by the University of Alaska Museum of the North and the National Park Service, Fairbanks Office. The standards were also analyzed on the Thermoscientific Niton XL3t XRF analyzer. On the Bruker pXRF, each of the nine standards were analyzed three times at 40KeV and 15mA for 200 seconds using the black copper filter and repeated with no filter. Then the nine standards were analyzed three times each on the Niton pXRF using the Test All Geo routine generally used for rocks, for at least 90 seconds encompassing low, medium, and high energies (30 seconds at each energy). Then the standard raw counts (Bruker) or concentrations (Niton) collected by each device using the different routines were plotted against known concentrations of each element (Zr, Sr, Rb, Zn, Ni, FeO, MnO, BaO, Nb, Cr2O3, V, TiO2, CaO, K2O, S) (Appendix C). The elemental concentrations collected from the standards that formed a regression line with an R^2 value greater than .9 were accepted for calibration. The Niton ThermoScientific ED-pXRF proved most reliable for most of the elements, so this device was employed in this study (Appendix C).

Upon determining that the Niton pXRF would be the most appropriate device for analyzing the material related to this study, all the bedrock quarry samples that were analyzed on the WD-XRF were also analyzed on the Niton ED-pXRF. All the artifacts were also analyzed on the Niton. Because artifacts must be analyzed on the non-destructive Niton pXRF, making discriminate groups of the quarries using Niton chemical data would eliminate instrumentation bias when attempting to assign artifacts to quarry groups. Concern with using the Niton pXRF chemical data to create discriminant groups for the quarries includes a smaller analytical surface than the WD-XRF, such that the WD-XRF can account for a larger amount of chemical variation in a single sample. To mitigate bias to the chemical signatures of each sample on the Niton pXRF, each sample was analyzed three times on a different location on the surface of the sample. The average of the values obtained from the three analyses of the surface of each sample is used as the chemical signature of each sample. Additionally, a concern with the Niton data is that it is not as accurate and precise for a flat analytical surface as the WD-XRF, such that the WD-XRF provides the ‘best’ values for each quarry sample. To test precision and accuracy of Niton, chemical values for all of the quarry bedrock samples were tested based on linear regression comparison to WD-XRF values for each element that could be measured on both the Niton pXRF and the WD-XRF. Because quarry samples are less homogenous than the standards, elements with regression line R^2-values greater than 0.7 were accepted as reliable. Further, stepwise discriminant function analysis was performed on both the WD-XRF quarry sample value and the Niton pXRF quarry sample values to see if the same elements were selected and if the groupings were accurately assigned based on values collected from each device. The elements that were selected to distinguish the two quarry groups using stepwise discriminant function analysis overlapped for each device, though the WD-XRF analysis included more elements as predictor variables than the Niton analysis. This is expected based on the detection limits of the Niton pXRF in comparison to the WD-XRF, and it is also a good indicator that Niton quarry sample can reliably be used to discriminate the Landmark Gap Quarry and Long Tangle Lake Quarry groups, as well as be used to make the artifact chemical assignments to the quarry groups.

Other concerns in calibrating the non-destructive ED-pXRF include the effects of the cortex and irregular surfaces. Analysis of cortex on the bedrock quarry samples indicated that cortex weathering has a major effect on the results collected on the Niton pXRF. However, the pXRF remains reliable to analyze non-cortical but slightly irregular surfaces, such as the ventral surface of an artifact. This was found by analyzing the artifacts that were destructively analyzed on the WD-XRF with the Niton pXRF, comparing the flat surface concentrations to the irregular surface Niton pXRF concentrations. Relatively high correlations indicate that artifacts without cortex can be somewhat reliably analyzed with the Niton pXRF and the subsequent measured concentrations can be compared to the Tangle Lakes quarry concentrations. That is, as long as the interior surfaces of the artifacts are measured and not cortex, the concentrations so measured are relatively reliable.

4.8 ED-XRF Artifact Sourcing

Stepwise discriminant function analysis (DFA) was ultimately used to determine: (1) the elements that best distinguish Landmark Gap Quarry and Long Lake Quarry based on the elemental concentrations in bedrock samples from each quarry; (2) discriminant functions for each quarry predict the group assignments for samples with unknown origin. In order to perform discriminant function analysis, the data should possess several characteristics. Data should (1) consist of continuous variables, (2) be normally distributed, (3) be linearly related, (4) and have equal variance in each group (Poulsen and French 2008). Each of these criteria was evaluated with regards to the dataset for the two quarries.

1) Sample size: "Unequal sample sizes are acceptable. The sample size of the smallest group needs to exceed the number of predictor variables. As a "rule of thumb", the smallest sample size should be at least 20 for a few (4 or 5) predictors (Poulsen and French 2008:3).

2) Normal distribution: “It is assumed that the data (for the variables) represent a sample from a multivariate normal distribution. You can examine whether or not variables are normally distributed with histograms of frequency distributions. However, note that violations of the normality assumption are not "fatal" and the resultant significance test are still reliable as long as non-normality is caused by skewness and not outliers,” see discussion in Tabachnick and Fidell (1996), (Poulsen and French 2008:3).

3) Outliers: “DFA is highly sensitive to the inclusion of outliers. To mitigate this, it is possible to run a test for univariate and multivariate outliers for each group, and transform or eliminate them. If one group in the study contains extreme outliers that impact the mean, they will also increase variability. Overall significance tests are based on pooled variances, that is, the average variance across all groups. Thus, the significance tests of the relatively larger means (with the large variances) would be based on the relatively smaller pooled variances, resulting erroneously in statistical significance” (Poulsen and French 2008:3). Box-and-whisker plots were used to identify outliers in the two quarry datasets, and the outliers were eliminated (Hodge and Austin 2004).

4) Homogeneity of variances/covariances: “DFA is very sensitive to heterogeneity of variance-covariance matrices. Before accepting final conclusions for an important study, it is a good idea to review the within-groups variances and correlation matrices. Homoscedasticity is evaluated through scatterplots and corrected by transformation of variables” (Poulsen and French 2008:3). Homogeneity of variance within the quarry groups (Group 1 being Landmark Gap Quarry samples and Group 2 being Long Tangle Lake Quarry) was determined using the Levene test of homogeneity of variances. The null hypothesis of this test is that there will be homogeneity of group variance in a population. If there is lack of homogeneity of group variance it is still possible to perform DFA. However, a solution to recognizing the lack of homogeneity of variance in the groups is to test the consistency of group assignments using Mann-Whitney U test, Student’s t-test, and Welch’s unequal variance t-test. These tests are applied after performing the DFA when predicted group assignments have been made according to the known groups that were input to the DFA. Mann-Whitney U tests are applied to data that is not normally distributed, has heterogeneity of variance, and only two samples are compared. Welch’s unequal variance t-test is applied to data that is normally distributed and has heterogeneity of

variance. Student's t-test is applied to data that are normally distributed and has homogeneity of variance. The null hypothesis of these tests is that there is no significant difference between groups, and the null hypothesis should be rejected if the p-value is less than 0.05.

Stepwise discriminant function analysis was performed on the elemental concentrations of the quarry samples separately using both the Niton pXRF and WD-XRF. All the samples from each quarry were included in the same discriminant function analysis. Since the samples were extracted from the bedrock of each quarry, it is known with certainty the origin of the quarry samples. These original quarry sample groups were distinguished: group 1 is composed of Landmark Gap Quarry samples, and group 2 is composed of Long Tangle Lake Quarry samples. Stepwise discriminant function analysis predicts the group association of the quarry samples from concentrations, by removing elements that confound the groupings. If groups are accurately predicted, known group 1 samples will be statistically predicted to be associated with group 1, and known group 2 samples will be statistically predicted to be associated with group 2.

Subsequently, stepwise discriminant function analysis was performed on the dataset including all the quarry samples and the artifact samples. The quarry samples are associated with known groups and are labeled group 1 and 2. The artifact samples have an unknown origin and are labeled as group three (unknowns). The elements removed from the quarry groupings as a result of the first stepwise discriminant function analysis were not included in the stepwise discriminant function analysis to predict the group assignments of the artifacts. No additional elements were removed based on the stepwise discriminant analysis of all the samples, including the unknown artifact group. The expectations for the discriminant analysis of the dataset including the artifacts are different than the expectations for the discriminant analysis of the dataset including only the quarry samples. It is expected that the group 1 quarry samples will be predicted as group 1, the group 2 quarry samples will be predicted as group 2, and the artifacts will be predicted as group 1, 2, or 3. The artifacts that are predicted to be associated with group 1 and 2 are given a probability value to determine the certainty with which the artifacts should be assigned to one of those groups. The predicted group of the artifacts is interpreted as the artifacts originating at Landmark Gap Quarry, Long Tangle Lake Quarry, or an unknown source.

To further test the robusticity of the quarry assignments homogeneity of variance within each group was evaluated, using Student's t-tests, Welch's unequal variance t-test, and Mann-Whitney U tests according to the steps outlined above. Finally, a reanalysis with a holdout sample, which was 25% hold out from the total sample, was performed to further test the robusticity of group assignments.

4.9 Lithic Debitage Analysis

Attributes recorded on individual flakes in debitage assemblages can be analyzed individually or as a population (Andrefsky 2005). The qualitative and metric attributes recorded on each flake are grouped and analyzed in terms of raw material type, thus assuming that variables associated with raw material type will cause variability in each debitage assemblage. Raw material typology that will be used to group the debitage are types based on visual variability in the lithic toolstone in the assemblages. Quantitatively rigorous raw material designations are only possible based on the artifacts that could be chemically assigned to the quarries. Artifacts that were qualitatively grouped into raw material types based on color, grain size, and texture are re-grouped into local and non-local materials based on patterning in lithic attributes associated with distance-decay principles.

4.10 Local and Non-Local Material Estimations

Lithic attribute analysis in terms of raw material type is possible with the knowledge of the source of the artifacts analyzed by the Niton, however the material types of the assigned unknowns and the unassigned unknowns must be relative. Analysis of the unknown material in terms of a local and nonlocal material scale is possible using the evidence from the assigned groups. Multiple lines of evidence can be used to classify the assigned unknowns and the unassigned unknowns to local and non-local groups. All the artifacts were initially assigned a raw material code based only on qualitative traits such as Munsell color, quality, and estimated rock type (Appendix D). These qualitative assignments were retained to compare to the actual artifact assignments and group non-local and local materials. The qualitative raw material groupings were the best estimations with which to group the variation in the material of the artifacts that were not assigned to a quarry. However, it is known that these raw material groups are inaccurate at the scale of the individual material groups, but they may be more accurate in terms of the local/nonlocal scale. Aggregate analysis of certain lithic attributes has demonstrated clear patterning for material that was acquired locally verses non-locally based on general principals of distance-decay models (Ozbun 1991; Renfrew 1977). Attributes on artifacts that are associated with distance of material transport and reduction stage are amount, size, cortex amount, and dorsal scar count (Bradbury and Carr 1995; Carr and Bradbury 2001; Odell 2004). The amount of a raw material type in an assemblage is expected to decrease as distance from the source increases. Flake size, and cortex amount is also expected to decrease as distance increases. Finally, dorsal scar count is expected to increase as distance increases suggesting that the material has be worked and reduced more as it moves farther from the source. These measures were first applied to the raw material groupings of the assigned unknown artifacts to re-assign them to local and non-local groups.

4.11 Models of Raw Material Distribution

Four models were created to test expectations about the raw material distributions in this site components. These include: (1) a Quarry Abundance Ratio which bases expectations for raw material distributions within site assemblages off of metric attributes of raw material available on the landscape; (2) an attractiveness/gravity model that incorporates physical constraints of the landscape and raw material sources that likely condition efficient behavior in terms of procuring and transporting material; (3) a distance-decay model applying distance as the only conditioning factor of material procurement and transport; and (4) a cost-distance decay model using terrain difficulty and distance as conditioning factors of material procurement and transport. The methods for developing and applying the models are outlined below.

Quarry Abundance Ratio

The Quarry Abundance Ratio (QAR) is a simplified adaptation of the Chert Abundance Ratio (CAR) of Soto et al. (2017). Soto et al. (2017:5) calculate the CAR based on volume of chert bearing formations, size of nodules, and occurrence of siliceous material such that the CAR "corresponds to the theoretical contribution of each outcrop to the geological formation in which it is included." The QAR was adapted and simplified from the CAR to fit the geological and archaeological context of the raw material in this study. The CAR is calculated for chert outcrops within a mapped chert formation that could extend for kilometers and the proportion or percent of the chert formation that occurs as each outcrop is expected to be a comparable proportion of an archaeological assemblage in the region. The raw material in this study is not chert, therefore toolstone quality formations are approximately 17,000 sq. meters (Landmark Gap Quarry (LMG)) and 3,550 sq. meters (Long Tangle Lake Quarry (LTL)). Toolstone quality rock is not exposed continuously at each quarry; however, because the quarries are isolated occurrences of metamorphic toolstone that occur over a relatively small area in comparison to a chert formation, the QAR can be quantified by comparing the abundance of material at two quarries.

Further, the two quarries are only about 7km apart with no other high quality toolstone source recorded to date between them. Therefore, the QAR is represented by the following equation:

Where n = number of exposures at the quarry, the ratio is Long Tangle Lake Quarry material abundance divided by Landmark Gap Quarry material abundance, based on the sum of the products of quality, size, and nodule size codes for each exposure.

$$\text{QAR} = \frac{\sum_{n=21}(LTLexpousre\ quality)(LTLexposure\ size)(LTLnodule\ size\ at\ exposure)}{\sum_{n=15}(LMGexposure\ quality)(LMG\ exposure\ size)(LMGnodule\ size\ at\ exposure)}$$

The ratio is meant to approximate the abundance of usable material at each quarry. If people were obtaining this material in a generalist procurement strategy such that material abundance was largely a factor in the amount that was obtained then the QAR ratio should be similar to the ratio of Long Tangle Lake Quarry Material and Landmark Gap Quarry Material occurring at each site.

Number of exposures

The number of exposures at each quarry is associated with the sampling locations, which were each exposed nodule or strike of toolstone quality material.

Size of exposures

This was estimated based on how much toolstone quality material was exposed at each exposure.

1. < 3 sq. meters
2. 3-7 sq. meters
3. > 7sq. meters

Size of nodules

This was estimated based on the ability to extract nodules of a certain size from bedrock during sampling with a rock hammer.

1. < 5cm^3
2. 5-15cm^3

3. >15cm^3

Material Quality

1. Low quality: Macrocrystalline (coarse grains >0.75mm in diameter), fractures along cracks or unpredictably, difficult to make conchoidal fracture, difficult to extract a large nodule to work.
2. Medium quality: Microcrystalline (fine grains visible with microscope), few inclusions (irregular cavities in otherwise homogeneous rock), usually fractures conchoidally.
3. High quality: Cryptocrystalline (grains <3µm), fractures conchoidally and makes a sharp edge, easy to extract a reduceable nodule.

<u>*Attractiveness Model*</u>

The attractiveness model tested with this data set has been taken from Wilson (2007b) and it attempts in incorporate all extrinsic factors of a raw material source that could influence raw material choice. The attractiveness equation is the same as that used by Wilson (2007b) but with slightly different criteria for the categorical values of the quantitively attributes of the raw material source. The equation is as follows for the attractiveness of a quarry (A(q)):

$$A(q) = \frac{(quality)(extent\ of\ source)(100)}{(difficulty\ of\ terrain)(cost\ of\ extraction)} \times \frac{size}{scarcity}$$

Therefore, unlike the QAR which holds qualitative behavioral factors equal, the attractiveness model incorporates how people would have interacted with the landscape and the quarry itself as conditioning factors beyond only what each quarry was capable of yielding.

The variables that are used in this equation overlap with the variable used in the QAR but are applied differently.

Material Quality

Each exposure that was sampled was given a score of 1, 2, or 3 based on the raw material quality. The sum of the quality scores for the exposures was taken from each quarry to represent this value.

1. Low quality: Macrocrystalline (coarse grains >0.75mm in diameter), fractures along cracks or unpredictably, difficult to make conchoidal fracture, difficult to extract a large nodule to work.

2. Medium quality: Microcrystalline (fine grains visible with microscope), few inclusions (irregular cavities in otherwise homogeneous rock), usually fractures conchoidally.

3. High quality: Cryptocrystalline (grains <3µm), fractures conchoidally and makes a sharp edge, easy to extract a reduceable nodule.

Extent of Source

The extent of each source was determined by the sum of the estimated size rank of the exposures. By adding the size of each exposure together the variable accounts for the number of exposures at each quarry. The total area of the quarry formation was not included because not all of the landforms have exposed rock and it is difficult to know how much more was exposed in between the Early and middle Holocene. The size of the exposure was estimated based off of how much toolstone quality material was exposed at each nodule or strike.

Size of exposure:

1. < 3 sq. meters

2. 3-7 sq. meters

3. > 7sq. meters

Size and Scarcity Ratio

Size refers to the estimated maximum volume of a nodule that could be extracted from each exposure of each quarry. The nodule size is divided by scarcity for each exposure. The product of these values for all the exposures at each quarry is taken to represent abundance of particular size nodules. The most abundant nodule size class was multiplied by the number of exposures ranked at the given value and then divided by the scarcity value. Then the second most abundant nodule size was multiplied by the number of exposures ranked at the given value and then divided by the scarcity value squared. Finally, Then the third most abundant nodule size was multiplied by the number of exposures ranked at the given value and then divided by the scarcity value cubed.

Size of nodules

This was estimated based on the ability to extract nodules of a certain size.

1. < $5cm^3$
2. $5\text{-}15cm^3$
3. >$15cm^3$

Scarcity

1. Very abundant (more than 50% of the surface area of the source consists of toolstone quality material)
2. Intermediate abundance (25-50% of the surface area)
3. Scarce (less than 25% of the surface area)

Difficulty of Terrain

Difficulty of terrain is a relative value calculated in ArcGIS 10.4 based on a cost surface consisting of friction factors of distance, slope and waterways. In the Tangle Lakes Archaeological District these physiographic features were likely relatively consistent over time and vegetation most likely did not create a major cost for travel. Due to the number of lakes and rivers it is likely that water was a barrier to movement when necessary to cross and an efficient form of movement when travel down current was possible. Ethno-historic use of canoes for hunting caribou by the Ahtna has been recorded at Paxson Lake, which is approximately 24km southeast of Long Tangle Lake. In the winter when lakes and rivers were frozen it is likely that the raw material sources were covered with snow, and therefore exploitation of raw material sources must take place in the summer when open water must be accounted for with regards to travel to and from the quarries. Further, slope provides a proxy for cost of walking uphill. The program will always assume it is more costly to walk uphill than down or on a flat surface. In navigating from the quarry to a site or from a site to a quarry, the cost surface will calculate a relative value for points on the map associated with traveling across the landscape in a particular direction. The value provided to represent terrain difficulty is not a real value that represents true human movement in calories or time because there are many more factors relating to human movement up and down inclines, around and across barriers than can truly be accounted for. Therefore, this model does not attempt to quantify movement in externally comparable terms but only calculates relative values attempting to provide slightly more detail than straight-line distance. Therefore, it can act as a relative proxy for cost factors that may have contributed to human movement. Further, calculating terrain difficulty based on roundtrip to each quarry to and from each site assumes that materials were directly procured. Roundtrip cost values for traveling from each site to each quarry and back were calculated by adding the values of each quarry and site location on cost surfaces

Cost of extraction

The cost of extraction relates to the degree of difficulty to obtain material from the quarry source. Some quarries require extensive quarrying procedures (Odell 2001; Torrence 1984), while others have loose nodules available to be picked up on the surface (Thacker 1996). A difficulty rank is applied to each exposure from each quarry and then the sum of the ranks for each exposure is taken to represent the cost of extraction for the whole quarry. Cost of extraction at the quarries was ranked based on relative difficulty to remove toolstone quality material nodules using a rock hammer.

1. Toolstone nodules available to pick up on the surface
2. Easy Quarrying
3. Hard Quarrying

Cost-Distance Decay

The cost-distance decay model expects as the cost of roundtrip travel between a site and a quarry increases, then the amount of material from that quarry in the assemblage should decrease in respect to a less costly source. The cost value was calculated in the same way as terrain difficulty value of the Attractiveness/Gravity model.

Distance-Decay

The distance decay model expects that material from the closest quarry to a site assemblage should be the highest proportion material at the site. The distance was calculated for round trip travel Euclidean distance between each site and quarry.

4.12 Diversity Indices

Diversity indices are useful for measuring the richness and evenness of raw material in component assemblages as a whole. Diversity refers to the measure of how many different materials are present in an assemblage and it is expected that diversity increases as distance from a source increases or the cost of obtaining material increases. Richness is another term to describe diversity such that increased richness is increased material diversity. On the other hand, evenness refers to the amount of each material represented, such that a large proportion of one material and small amount of a few others would not be an even assemblage (Odell 2004). Evenness is also expected to increase with cost increase from sources or distance increase from sources (Fowler 2014; Garvey 2015). The Shannon-Weiner H diversity measure and the Simpson's D are statistical measures of diversity performed in this study. Simpson's D is easy to comprehend as the diversity is a value between 0 and 1, 0 being low diversity and 1 being high diversity. Diversity measures are often used in biological settings to calculate species diversity in certain areas. In the context of this study raw material groups serve as the "species." The raw material diversity measures are calculated using best estimated and known raw material groups, such that the assigned Landmark Gap and Long Tangle Lake Quarry materials are included as groups and then the qualitative raw material type groups are incorporated into the diversity indices.

4.13 Individual Flake Attribute Analysis

The following variables were recorded on each flake in the debitage assemblages.

Qualitative measurements:

1) *Flake Type:* broken, complete, fragment, split, shatter (Prentiss 2001). The definitions for each variable associated with *flake type* are in Andrefsky (2005)
2) *Flake completeness*: complete, distal, medial, and proximal
3) *Technology type*: bifacial thinning, blade like flake, core like flake, damaged flake, decortication, shatter, simple
4) *Termination type:* feathered, hinge, stepped, overshot (Andrefsky 2005)
5) *Bulb Type:* salient or diffuse
6) *Lipping:* Present = 1, Absent = 0
7) *Thermal Alteration* = color, potlidding, crazing

8) *Platform Type:* NA (not present), complex, abraded, crushed, complex-broken, simple, cortical, simple-broken

Quantitative measurements:

1) *Size Class:* classes 1 – 10 increasing at 5cm increments.
2) *Cortex percent:* 0 = 0, >50% = 1, <50% = 2
3) *Dorsal Scar Count:* 0, 1, 2, 3, 4, >4
4) *Bulb of Force Thickness*
5) *Platform Thickness*
6) *Maximum Length*
7) *Maximum Width*
8) *Maximum Thickness*

4.14 Statistical Tests of Lithic Debitage

When evaluating technological patterns from attribute analysis it is important to be able to discern that observed difference between sets of data were actually a function of significant patterning and not chance. Pearson's chi-square test is used to test independence of two variables that are nominal, ordinal, or binary data with large sample sizes in order to determine if the two categorical variables are related. All of the variables associated with the debitage attribute analysis are categorical, such as flake type, dorsal scar count, flake completeness, erailure scar, etc. except for the metric measurements. The metric measurements are compared by assigning the individual flakes to size classes based on the metric measurements, thus evaluation of metric data is reclassified as ordinal data and applicable to Pearson's chi-square test.

Chapter 5: Results

5.1 Compositional Signatures

The goal of the chemical analyses, starting with the destructive WD-XRF, followed by informed use of non-destructive ED-pXRF is to answer the five following questions: (1) What kind of material is the common toolstone present at the two quarries? (2) Are the two quarries compositionally distinct, represented by intra-quarry homogeneity and inter-quarry heterogeneity? (3) What elements are important for distinguishing between the two quarries? (4) To what extent does material from Long Lake and Landmark Gap Quarries make up selected lithic assemblages in the Tangle Lakes Region?

5.2 Quarry Material

The materials from the Long Tangle Lake and Landmark Gap Quarries have been described over the years as chert, diorite, argillite, and unknown material (Table 5.1). It has also been cited as occurring in lithic assemblages are far away as Broken Mammoth, north of Delta , approximately 135km northeast of the Tangle Lakes, displayed in Table 5.2 (Yesner 2001). It is not surprising based on the visual analysis of bedrock material from the two quarries that defining the material is problematic. Visual distinctions are difficult to make between the two quarry materials because of the variety of colors and textures and highly variable weathering of cortex contributes to significant overlap in visual characteristics of material from each quarry (Figure 5.1). Based on the results of this study, quarry identifications based solely on visual characteristics are not reliable due to the weathering of the artifacts, and chemical analysis is required to distinguish among these quarries. Accurate sourcing of artifacts to one of the Tangle Lakes quarries requires that the bedrock at each quarry are completely different, so that each will have a distinct chemical signature. The results of qualitative microscope analysis of cut surfaces of samples from each quarry and subsequent WD-XRF elemental measurements allow for accurate definition of the Tangle Lake Quarries as two completely different metamorphosed materials with distinct compositional signatures.

Table 5.1 Tangle Lake area quarry materials as classified by previous workers.

Author	Year	Definition
Brady and Chorney	1973	Chert and diorite
West	1974	Chert
Mobley	1982	"Local fine-grained material…exact composition is in question" (Mobley 1982:93) Chert
Bowers and Bonnichsen	1983	Argillite
Gillispie	1992	Landmark Gap Chert
West	1996	Argillite ("chert," "welded tuff")
VanderHoek, Tedor, and McMahan	2007	Tangle Lake argillite
VanderHoek	2011	"Flakeable stone"

Table 5.2 Tangle Lake area quarry materials as referenced in archaeological sites outside of the Tangle Lakes.

Author	Year	Definition
Yesner	2001	Tangle Lake chert
Potter	2005	Landmark Gap (chert)
Blong	2018	chert linked to the upland Landmark Gap Source

The geological classification of the quarry materials is based on several lines of evidence, but primarily their chemical compositions, from WD-XRF. Contact metamorphism of these materials was determined from several indicators:

(1) Gabbro clearly intrudes-the quarry units (Figure 3.2, Figure 3.3). To test the presence of gabbro at the quarry sites non-toolstone quality bedrock was sampled surrounding the quarries and among the high-quality toolstone material. The non-toolstone quality material is compositionally distinct and clearly geochemically different from the high-quality toolstone quarry materials and is compositionally defined

as gabbro (Figure 5.2). Gabbro is an intrusive igneous rock; it was a magma with a temperature of about 1000 C that has intimately intruded the toolstone units, causing them to be heated at low pressure.

(2) Several quarry samples show high concentrations of calcium (WD-XRF). For sediments deposited in water, the predominant Calcium (Ca)-bearing mineral is calcite; identified by its effervescence in 10% HCl. The lack of such reaction for the high-Ca quarry rocks indicates a mineralogical reaction took place that consumed the calcite to make Ca-silicate minerals. Such happens when calcite-bearing rocks are heated at low pressure, through reactions such as:

$CaCO_3$ (calcite) + SiO_2 (quartz) ➔ $CaSiO_3$ (wollastonite) + CO_2.

(3) Visual analysis of XRF sample polished flat surfaces shows pyrite cubes variably present at each quarry (Figure 5.3). Pyrite in sedimentary rocks occurs as microscopic 'framboids'; the cubic shape is the result of thermal recrystallization.

WD-XRF analysis of all 157 quarry samples (68 samples from Landmark Gap Quarry and 89 from Long Tangle Lake Quarry) showed that the most dramatic difference between rocks of the two quarries is in their SiO2 contents, but also FeO, TiO2, CaO (Figure 5.4 a, b, c, d). Long Tangle Lake materials average 88 ± 3 %SiO_2 ; Landmark Gap materials average 77 ± 2% SiO_2. Of these two, the Landmark Gap quarry materials are easier to categorize geologically.

All of the Landmark Gap Quarry rocks plot in or immediately adjacent to the 'rhyolite' field of Figure 5.2. In addition, the average concentrations for the samples closely resemble those for average rhyolite (Table 5.3), as taken from Faure (1991). These compositional similarities cannot simply be coincidental. The largest discrepancy is for K2O, for which Landmark Gap Quarry material contains about ¼ that of average rhyolite. Texturally, many samples from the Landmark Gap Quarry are banded and (or) contain abundant visible sub-millimeter grains (Figure 5.1). I interpret their granularity and banding as due to deposition of rhyolitic material in water following an explosive eruption of rhyolitic magma. I interpret the loss of K to extensive leaching of hot grains during their deposition into water. Such a rock, the product of redeposition of a volcanic eruption is termed a 'tuff' and due to the thermal metamorphism, I designate these rocks as 'meta-tuff'.

Table 5.3 Compositional comparison of average Landmark Gap Quarry (LMG) rock to average rhyolite.

Weight percent oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	BaO
LMG	3.0	1.6	10.4	77	0.06	0.7	1.8	0.5	0.1	4.6	0.1
avg rhy[1]	3.5	1.6	13.4	75	0.06	2.5	2.1	0.5	0.1	3.8	0.1
part per million element											
	Cu	Ga	Mo	Nb	Rb	S	Sr	V	Y	Zn	Zr
LMG	15	14	7	11	43	318	351	143	42	40	128
avg rhy[1]	30	17	3	20	110	300	440	88	35	60	140

[1]average rhyolite, from Faure (1991)

Classification of the Long Tangle Lake Quarry rocks is more problematic due to their peculiar compositions and uncertain classification criteria. Chert is a fine-grained, SiO_2-rich rock, but exactly how much SiO_2 is required to classify a material as chert is nowhere (to my searching) stated in the archeological literature. Geologists, such as Hein et al. (2002) distinguish between 'chert' and 'cherty shale' or 'cherty argillite' at a SiO2 concentration of about 95% and a SiO2/Al2O3 ratio of about 40 (Figure 5.5). Coincidentally, the division between quartz-rich sandstone and sandstone is at about the same SiO2/Al2O3 ratio, allowing one to use a single diagram to classify both types of sedimentary rocks. Consequently, based on their high, but not extremely high, SiO2 concentrations, rocks of the Long Tangle Lake Quarry could be described as 'chert' but not as chert *per se*.

An odd characteristic of the rocks from the two quarries is that for many elements, but especially those least soluble in water, the average concentrations for rocks of Landmark Gap Quarry are close to two times those concentrations in rocks of the Long Tangle Lake Quarry (Figure 5.6). The average ratio for the nine elements is 1.9. This cannot be a coincidence. Rather, this relationship implies that the SiO2-rocks of the Long Tangle Lake Quarry must have an origin related to those of the Landmark Gap Quarry. I propose that the Long Tangle Lake Quarry rocks also represent tuffs, but ones for which the more soluble elements (e.g., Ca, Mg, Na, K) have been leached so that the less soluble ones were 'diluted' by additional SiO2. How exactly this happened is beyond the scope of this study but may be related to the very high BaO (up to 5.2 wt%, average 1.2 wt%) and high S (maximum 1.3%, average 0.2%) concentrations in these rocks. Typical cherts, for example, contain much lower BaO

(<.01%) and S (<.01%). In any event, none of the rocks has high enough aluminum to be considered argillite, or for argillite to have been the parent material prior to metamorphism (Figure 5.2).

Unfortunately, there really isn't a simple 'name' for the SiO2-rich rocks of the Long Tangle Lake Quarry. From a geologic perspective 'siliceous hornfels' is appropriate, hornfels is a generic name for a fine-grained, hard, contact metamorphosed rock (Figure 5.5), but of little value to an anthropologist. I propose 'chert-like' as a compromise between their composition and origin on one hand (not chert) and their appearance and properties on the other.

In sum, rocks of the two quarries are quite distinguishable. Elements that best distinguish the two materials based on WD-XRF data are: SiO_2 (Figure 5.4a), FeO (Figure 5.4b), TiO_2 (Figure 5.4c), CaO (Figure 5.5d), Al_2O_3, V, Na_2O, Zr, BaO and S. Rocks of the Long Lake quarry contain higher concentrations of Si, Ba, S, and Mn. Rocks from the Landmark Gap quarry are lower in Si, but higher in virtually all other elements (Table 5.4).

Figure 5.1 Bedrock samples cut and prepared for analysis on the WD-XRF. Left: Interior cut surfaces of bedrock samples are all ~ 4 cm diameter. The two left columns are samples from the Landmark Gap Quarry; the two right are from the Long Tangle Lake Quarry. Right: Cortical surfaces of quarry bedrock samples are all ~ 4 cm diameter. The two left columns are samples from the Landmark Gap Quarry; two right columns from the Long Tangle Lake Quarry.

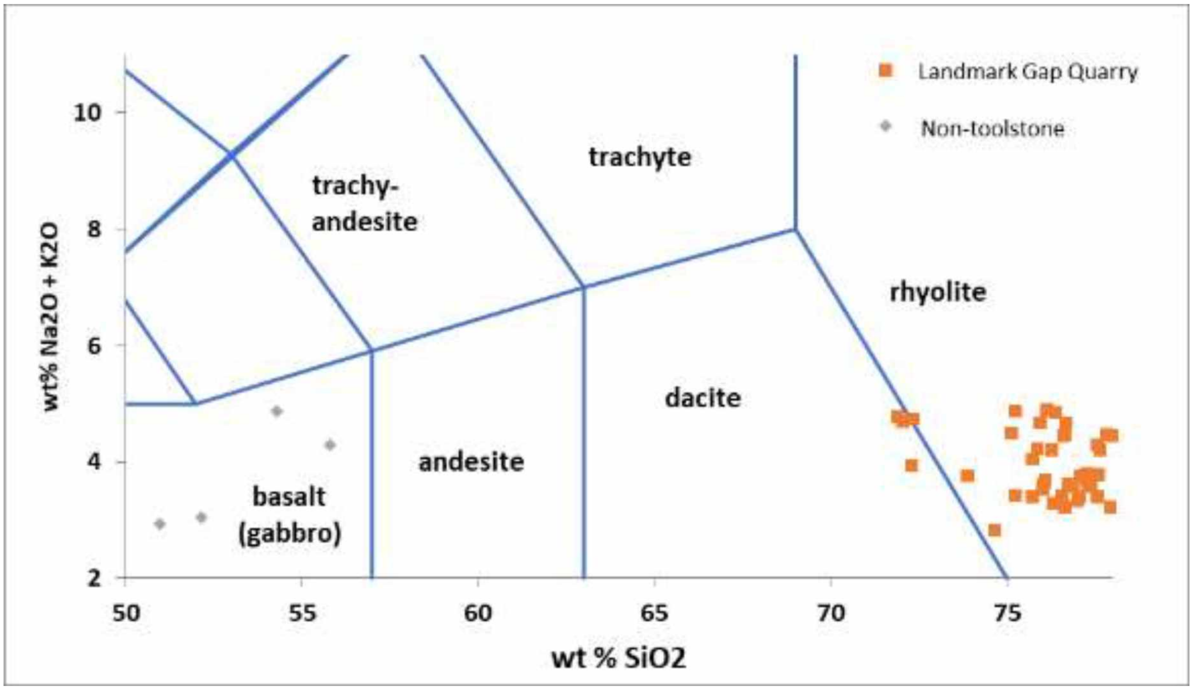

Figure 5.2 Chemical composition of (non-toolstone) gabbro samples compared to Landmark Gap Quarry samples. The graph uses the igneous rock classification diagram of x and Y, SiO2 and [Na2O + K2O], respectively, modified from Le Maitre et al. (1989).

Figure 5.3 Example of cube shaped pyrite (yellow, center) in quarry sample from Long Tangle Lake. The inset is an image of the entire cut sample face.

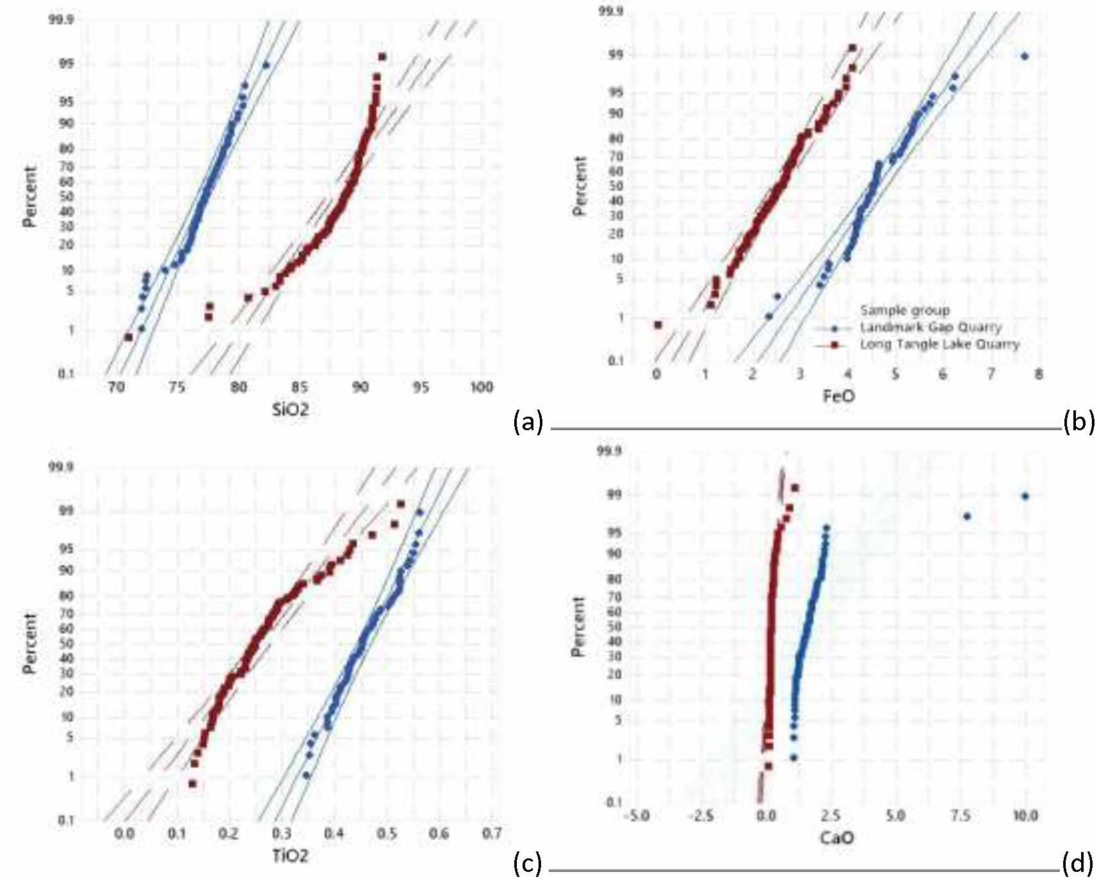

Figure 5.4. (a) SiO2, (b) FeO, (c) TiO2, (d) CaO content probability plots showing difference in the quarry concentrations of each compound alone. X-axsises are elemental concentrations in weight%.

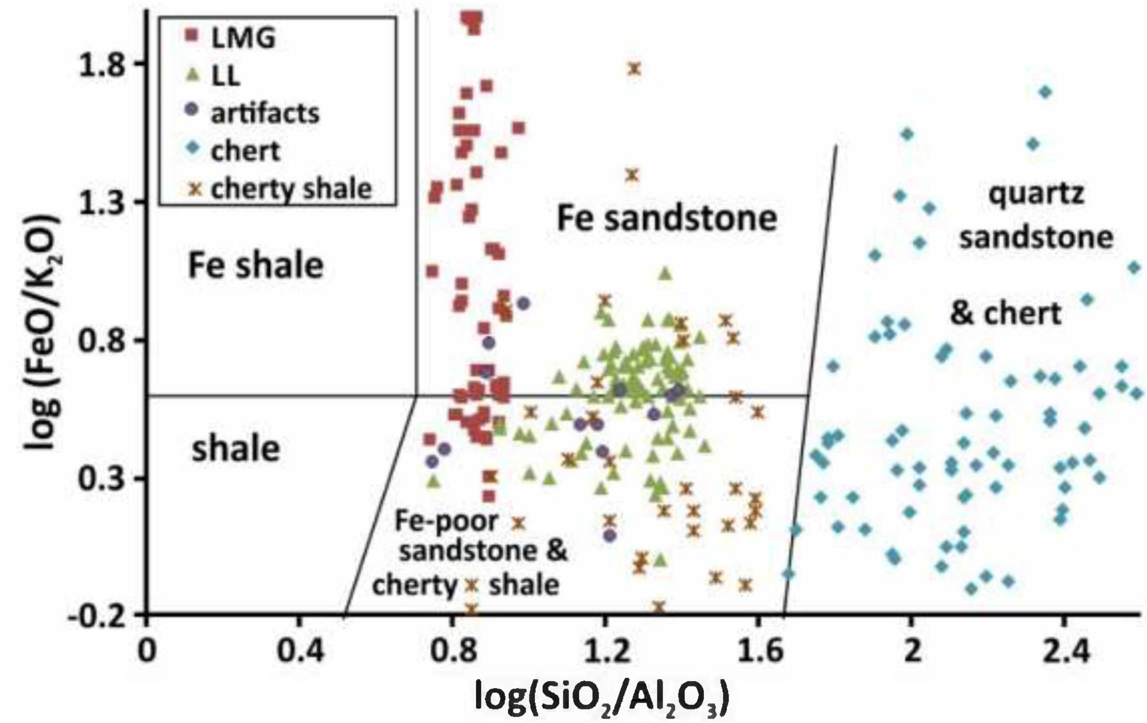

Figure 5.5 Classification of rocks from the study area based on chemical compositions, modified from Herron (1988). Compositions of chert and 'cherty shale' from Hein et al. (2002) and Reifenstuhl et al. (2009).

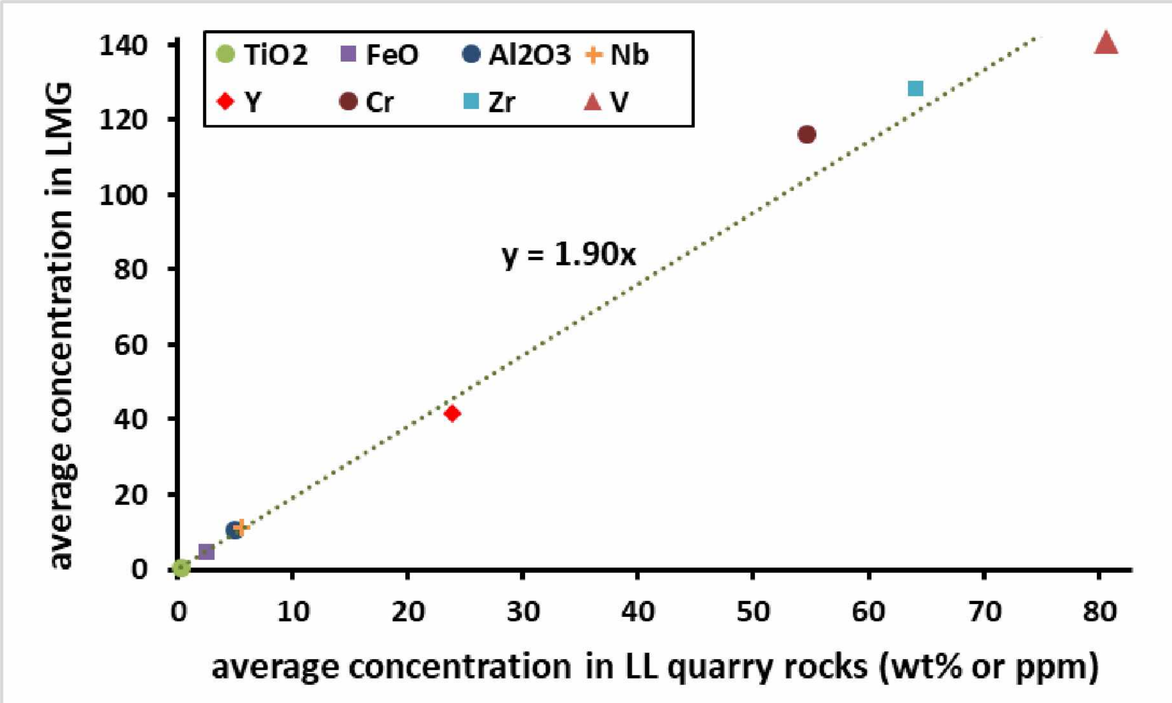

Figure 5.6 Average concentrations in the Long Tangle Lake quarry (LL) rocks verses average concentration of the same element in Landmark Gap quarry (LMG) rocks for many 'immobile' elements and oxides. Oxides are in wt% and elements in parts per million. The average ratio is 1.9.

Table 5.4 Compositional contrast between rocks of the Long Lake (LL) and Landmark Lake (LMG) quarries. The table shows the average (Av) concentrations of each element from the samples from each quarry and their standard deviations (stdev).

	weight percent											**ppm**		
	SiO_2	**BaO**	**S**	**MnO**	**FeO**	**Na_2O**	**Al_2O_3**	**CaO**	**MgO**	**TiO_2**		**Cr**	**Zr**	**Ni**
LL av	**88**	**1.2**	**0.2**	**0.21**	2.5	1.0	4.9	0.2	0.9	0.26		37	64	23
stdev	3	1.0	0.2	0.26	0.7	0.4	1.6	0.15	0.4	0.08		15	21	17
LMG av	77	0.2	0.03	0.09	**4.6**	**3.0**	**10.4**	**1.8**	**1.6**	**0.46**		**80**	**128**	**84**
stdev	2	0.1	0.05	0.03	0.8	1.0	1.0	1.3	0.3	0.05		15	45	28

5.3 Selecting a Non-destructive Analytical Device

It is preferable to use ED-pXRF on artifacts because it is non-destructive; however, its analytical capabilities are limited in comparison to the WD-XRF. Though the ED-pXRF is less susceptible to surface irregularities than the WD-XRF, it can only measure 25 mid-Z elements, sulfur (S) through uranium (U). The detection limits for the elements close to the margins of what the device is capable of measuring may be problematic such that the device will not detect S in every sample if it was present in small quantities as recorded by the WD-XRF.

As discussed in Chapter 4, two nondestructive ED-pXRF analyzers were available to chemically analyze the artifacts for this project, a Bruker pXRF (Bruker) and a ThermoScientific Niton XL3t XRF analyzer (Niton). Both the Bruker and Niton data were evaluated to determine which device is most appropriate for analyzing the meta-tuff and meta-chert present at the two quarries and presumably in the artifact assemblages.

The elements that were shown to be important for distinguishing the quarries based on the WD-XRF data were evaluated for comparability on the Bruker (Cu filters at 10KeV/15mA) and Niton using USGS homogeneous standards to evaluate SiO2, FeO, V, TiO2, CaO, Al2O3, Na2O, Zr, BaO and S. The elements Zn ($r^2 = 0.92$), Sr ($r^2 = 1$), CaO ($r^2 = 0.99$), BaO ($r^2 = 0.99$), FeO ($r^2 = 0.97$), were comparable to the actual values when collected on the Bruker. CaO ($r^2 = 1$), FeO ($r^2 = 1.0$), MnO ($r^2 = 0.97$), Pb ($r^2 = 1$), Zn ($r^2 = 1.0$), BaO ($r^2 = 1$), K2O ($r^2 = 1.0$), TiO2 ($r^2 = 1.0$), Cr2O3 ($r^2 = 1.0$), Rb ($r^2 = 0.99$), Sr ($r^2 = 1.0$), Zr ($r^2 = 1.0$), Nb ($r^2 = 0.99$), Ni ($r^2 = 1.0$), were comparable on to the actual values on the Niton. Therefore, the Niton was selected to proceed with chemical evaluation of the quarry and lithic samples. Evaluation of all 157 quarry samples on the Niton showed comparability of FeO ($r^2 = 0.93$), BaO ($r^2 = 0.91$), TiO2 ($r^2 = 0.92$), Zr ($r^2 = 0.72$), Sr ($r^2 = 0.89$), K2O ($r^2 = 0.97$). Refer to Appendix D for bivariate plots of the elements discussed above.

5.4 Discriminant Function Analysis of Quarry Signatures

The consistency between the Niton and the WD-XRF standards data for most elements capable of being collected is enough that the chemical data collected on artifacts by the Niton should reflect the true values of the quarry material obtained from the WD-XRF. However, there is still possibility of instrumentation bias when attempting to assign artifacts to quarries based on chemical signatures obtained from two different analytical devices. To alleviate this potential bias, discriminant quarry groups were created using the WD-XRF data and the Niton data separately.

The data's adherence to the assumptions of the DFA, which must be satisfied prior to performing the DFA are outlined below:

1) Sample size: Sulfur was the only element that was removed from analysis due to a small sample size.

2) Normal distribution: "Most distributions are leptokurtotic and "outperform" normally distributed data with respect to their ability to discriminate differences between sources. Those that are platykurtotic (Landmark Gap Quarry samples on the Niton: Nb, BaO, Rb, and Cr203; Long Tangle Lake Quarry samples on the Niton: TiO2; Landmark Gap Quarry samples on the WD-XRF: BaO, Zr, Ga, MnO, TiO2, K2O, SiO2, AL203, MgO, Na2O; Long Tangle Lake samples on the WD-XRF: W, Sr, Ga, Ni, TiO2) mostly fall between -2.0 and 2.0 and hence are only mildly affected. When turning to the datasets in which outliers have been eliminated, most variables have a slightly platykurtotic distribution (i.e. between 1.0 and -1.0)" (Brian Hemphill, personal communication, September 12, 2018), (Appendix E). Therefore, with the elimination of outliers there is such minimal departure from normality, it is not a problem for applying DFA to the dataset of quarry samples.

3) Outliers: Outliers were eliminated from the two quarry datasets based on box and whisker plots (Hodge and Austin 2004), (Appendix E).

4) Homogeneity of variances/covariances: Homogeneity of variance within the quarry groups (Group 1 being Landmark Gap Quarry samples and Group 2 being Long Tangle Lake Quarry) was determined using the Levene's test for homogeneity of variance. The null hypothesis was rejected for Zr, Sr, Rb, Zn, MnO, BaO, Nb, Cr2O3, TiO2, CaO, K2O. The null hypothesis was accepted for FeO (Appendix F). This means that there is not homogeneity of group variance for most of the elements involved in the analysis. The dataset may be used in the DFA; however, Mann-Whitney U tests, Student's t-tests, and Welch's unequal variance t-tests were applied after performing the DFA when predicted group assignments have been made according to the known groups that were input to the DFA. Mann-Whitney U test was applied to K2O, CaO, BaO,

Rb, and Zr. Welch's unequal variance t-test was applied to TiO2, Nb, Ni, Zn, Sr, Cr2O3. Student's t-test was applied to FeO. Based on these tests for the appropriate elements the null hypothesis can be rejected for all the elements except K2O and Rb (Appendix F). Therefore, there is a significant difference between the means of the two groups based on CaO, TiO2, Nb, BaO, MnO, FeO, Ni, Zn, Sr, Zr, and Cr2O3 (Appendix F)

The DFA of the quarry samples of both the WD-XRF data and the Niton data performed perfectly, such that 100 percent of Landmark Gap Quarry samples included in the analysis were statistically assigned to Landmark Gap Quarry and 100 percent of Long Tangle Lake Quarry samples included in the analysis were statistically assigned to the Long Tangle Lake Quarry (Table 5.5; Table 5.6). The stepwise DFA calculations systematically eliminated samples from the analysis that were missing a predictor variable (element) concentration. These samples therefore did not contribute to the final grouping functions. Further, stepwise DFA was performed such that elements were eliminated incrementally that did not contribute to distinguishing between the two quarries. The results of the WD-XRF stepwise DFA showed that K2O, CaO, MnO, FeO, Zn, Rb, Sr, and Zr were best for predicting the quarry groupings (Table 5.7; Figure 5.7), and 100 percent of the samples were assigned to the correct quarries based on these predictor variables (Appendix G). The maximum elements that were included in the DFA analysis of the WD-XRF data were the elements that were capable of being recorded on the Niton, because if artifact assignments were made using the WD-XRF quarry data and the Niton artifact data, any elements that could be recorded on the WD-XRF but not the Niton would not be useful. The stepwise DFA of the Niton quarry data selected Zr, Zn, FeO, MnO, and CaO as optimal predictors of quarry groupings (Table 5.7; Figure 5.8). Additional information about Niton quarry sample analyses may be found in Appendix E. The results obtained from the Niton data show the consistency in the rock compositions from the quarries transcending the devices, such that the Niton and WD-XRF selected the same elements, but the WD-XRF selected more because it has better accuracy and precision for more elements, that is Sr, K2O, and Rb may not be as reliable on the Niton, as with the WD-XRF. Further, artifact compositions collected using the niton will perform best for predicting artifact sources when using DFA of the compositional data collected with the Niton. I used these elements: Zr, Zn, FeO, MnO, and CaO, because 100 percent of the samples were assigned to the correct quarries based on these predictor variables (Appendix H). A secondary DFA was performed with a holdout sample (25% withheld) to test the robusticity of the grouping predictions (Appendix I). With a smaller sample, 100% of the samples were assigned to the correct quarry, however only Zr, Zn, FeO, and CaO were selected as predictor variables (Appendix I). Since the DFA with the entire dataset was consistent with the results of the holdout dataset, with the exception of one more element, the selected elements from the entire dataset were used when making artifact assignments using DFA.

Table 5.5 WD-XRF quarry sample discriminant function classification from known quarry group membership to predicted group membership.

			Predicted Group Membership		
			Landmark Gap Quarry	Long Tangle Lake Quarry	Total
Original	Count	Landmark Gap Quarry	44	0	44
		Long Tangle Lake Quarry	0	45	45
	%	Landmark Gap Quarry	100	.0	100
		Long Tangle Lake Quarry	0	100	100
a. 100.0% of original grouped cases correctly classified.					

Processed		163
Excluded	Missing or out-of-range group codes	0
	At least one missing discriminating variable	74
Used in Output		89

Table 5.6 ED-pXRF quarry sample discriminant function classification from known quarry group membership to predicted group membership.

			Predicted Group Membership		
			Landmark Gap Quarry	Long Tangle Lake Quarry	Total
Original	Count	Landmark Gap Quarry	54	0	54
		Long Tangle Lake Quarry	0	62	62
	%	Landmark Gap Quarry	100	0	100
		Long Tangle Lake Quarry	0	100	100
a. 100.0% of original grouped cases correctly classified.					

Processed		160
Excluded	Missing or out-of-range group codes	0
	At least one missing discriminating variable	44
Used in Output		116

Table 5.7 WD-XRF and Niton ED-XRF quarry discriminating variables (elements) and associated function coefficients.

	Function 1 WD-XRF	Function 1 ED-XRF
K2O	.835	
CaO	1.089	.708
MnO	-.271	.-246
FeO	.654	.670
Zn	-.378	-.460
Rb	-.633	
Sr	-.494	
Zr	.254	.343

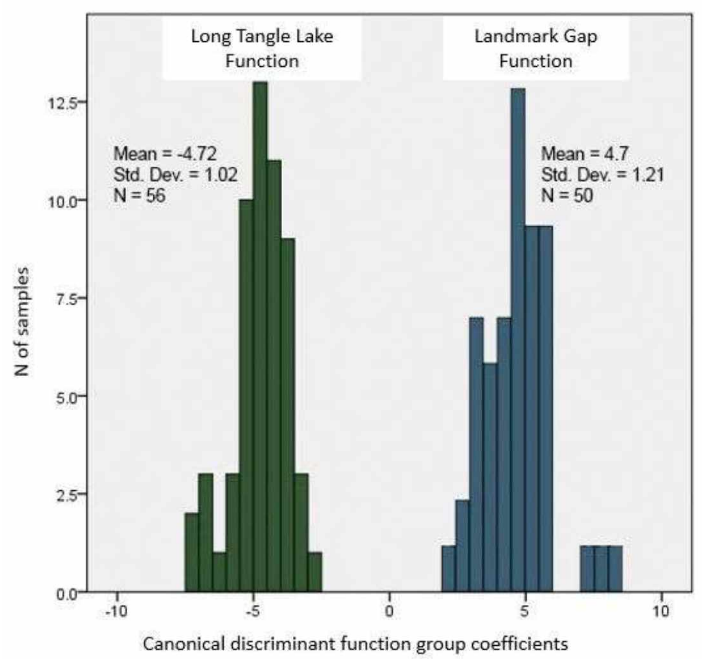

Figure 5.7 WD-XRF discriminant function distribution and descriptive statistics for the predicted Landmark Gap and Long Tangle Lake Quarry groups.

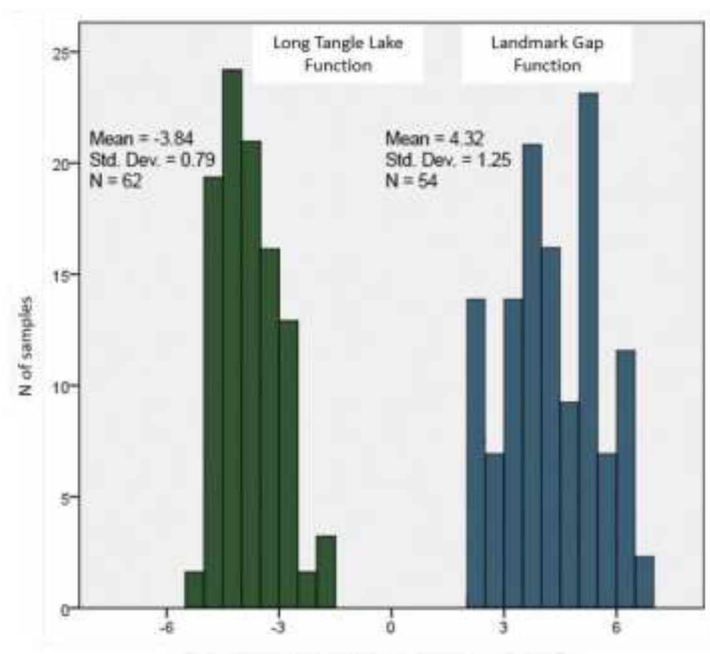

Figure 5.8 Niton discriminant function distribution and descriptive statistics for the predicted Landmark Gap and Long Tangle Lake Quarry groups.

5.5 Composition-based Artifact Assignments

All artifacts were analyzed by the Niton XL3t non-destructive ED-pXRF. Due to analytical restrictions based on minimum size and flatness of the artifact. Artifacts that met the criteria were selected. Lithic debitage attribute analysis was performed on the entire randomly selected debitage sample from each site component (Landmark Gap Trail Site, Whitmore Ridge Component 1 and Component 2, and XMH-35). Each flake analyzed for lithic attributes was also examined to see if it met the criteria for Niton analysis. 555 distinct artifacts from the total sample of lithic debitage from all four site components (n=1,603 flakes) were considered appropriate for reliable Niton analysis. This means that each of these flakes covered the x-ray beam with a non-cortical flat surface. All the Niton data associated with the 555 analyzed flakes were combined with the Niton quarry data in order to perform DFA that would predict the quarry group for the artifacts (Appendix J). The known groups prior to the DFA include the Landmark Gap Quarry samples, the Long Tangle Lake Quarry samples, and the artifacts for which sources are unknown and could be associated with multiple raw material sources. It is hypothesized that the results of the DFA including the quarry samples and artifact compositions will predict the quarry samples consistently to the appropriate quarry groups and the artifacts will be predicted to be associated with either of the quarry groups or the unknown group. It is also hypothesized that the artifact assignments will perform better when the DFA includes Niton quarry data and Niton artifact data, rather than WD-XRF quarry data and Niton quarry data because the WD-XRF quarry groups were predicted using more elements than could reliably predict the groups with the Niton data.

Stepwise DFA was performed to test these hypotheses, both with inclusion of the artifact Niton data and the WD-XRF quarry data (Appendix K), and separately with the Niton quarry data only (Appendix L). The stepwise DFA selected the same predictor elements for assigning the samples to the groups as when the artifact were not included, which serves as another indicator of the strength of the quarry groupings (Table 5.8). The DFA of all the data collected on the Niton (Appendix L) performed much better than the DFA with data collected on the WD-XRF and the Niton together (Table 5.9, Appendix K). Therefore, the artifact assignments made using DFA of the quarry samples analyzed on the Niton was accepted as the true quarry assignments (Table 5.9; Figure 5.9). Ultimately this information allowed for each artifact that was compositionally analyzed from each site component to be assigned to a quarry or unknown group (Table 5.10).

Table 5.8 Niton quarry discriminating variables (elements) and associated function coefficients for predicting artifact quarry group associations.

	Function	
	1	2
CaO	.669*	0.097
FeO	.458*	-0.232
MnO	-.259*	0.071
Zn	-.177*	0.144
Zr	0.493	.660*

Table 5.9 Niton quarry sample and artifacts discriminant function classifications from known group membership to predicted group membership. A total of 571 artifact compositions were assigned to a discriminant group this includes several artifacts that were analyzed twice. Therefore, only 555 distinct artifacts were analyzed.

			Predicted Group Membership			
			Landmark Gap Quarry	Long Tangle Lake Quarry	Unknown Quarry	Total
Original	Count	Landmark Gap Quarry	51	0	3	54
		Long Tangle Lake Quarry	0	62	0	62
		Unknown	174	148	249	571
	%	Landmark Gap Quarry	94.4	0	5.6	100
		Long Tangle Lake Quarry	0	100	0	100
		Unknown Artifacts	30.5	25.9	43.6	100
Valid					687	94%
Excluded		Missing or out-of-range group codes			0	0
		At least one missing discriminating variable			42	6%
		Total			42	6%
Total					729	100

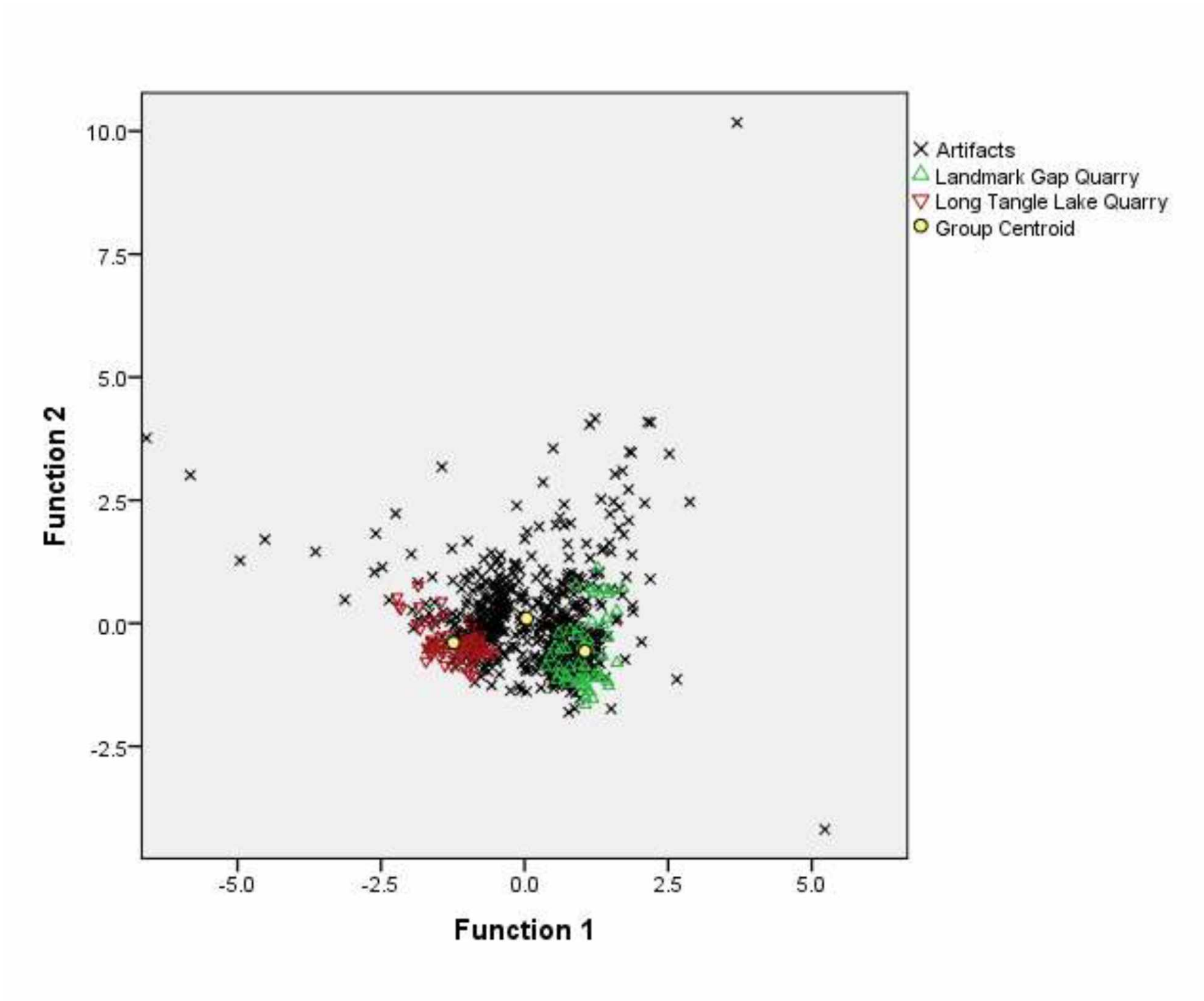

Figure 5.9 Niton discriminant function artifact and quarry sample distribution for the predicted quarry groups and assigned artifacts.

Table 5.10 Numbers of artifacts assigned to each quarry, group of unknown sources, or unassigned.

Site Component	Total Artifacts	Total Unassigned	Assigned to Landmark Gap Quarry	Assigned to Long Tangle Lake Quarry	Assigned to Unknown Sources
Whitmore Ridge C1	403	257	70	3	73
Whitmore Ridge C2	396	326	22	4	43
Landmark Gap Trail site	403	229	61	53	60
XMH-35	401	235	17	85	64

5.6 Archaeological Behavioral Results

Several lines of evidence can be combined to establish an understanding of human behavior between the Early Holocene and the Mid-Holocene in the Tangle Lakes region. Lithic debitage assemblages of four well-dated site components can be evaluated in terms of raw material and technological attributes. The chemical data presented above offer definitive evidence for the sources of artifacts that were chemically analyzed from these assemblages. The artifacts that were not chemically analyzed can be grouped based on estimations of local and non-local material. However, prior to understanding material use between site components and the use of different materials within site components, it is important to control for the variable to site type. Site type refers to the general purpose of the site, such that it will have some interplay with how materials were used at each site and subsequently how they were procured. If general trends of reduction strategies and tool production can be determined for each site component, then understanding how the raw materials fit into each overall site's strategy will provide better indication of specific procurement strategies and raw material use. Ultimately, the Niton data provides specific information about the number of artifacts that can be sourced to the Landmark Gap Quarry and the Long Tangle Lake Quarry. This line of evidence can effectively contribute to answering the questions outlined in this project which include:

(1) Is there differential treatment of the raw materials within each site component?

(2) How does the treatment two local Tangle Lakes quarry toolstone materials (Long Tangle Lake Quarry and Landmark Gap Quarry) compare to other local and non-local materials being used between the Early and Mid-Holocene?

(3) What procurement strategies can be identified for all the site components?

(4) Are human mobility and toolstone procurement strategies different between the Denali period and the Northern Archaic period?

(5) Does site type (e.g. residential verses lithic workshop) consistently influence procurement and mobility strategies between the Denali and Northern Archaic period?

(6) How does the technological organization and behavioral strategies correspond with the broader understanding of Early to Mid-Holocene archaeological patterns from previous research in the Tangle Lakes region and central Alaska? The results outlined below incorporate the chemical data into the archaeological dataset to answer these archaeological questions.

5.7 Establishing Site Type and Technology Strategies

Reduction stages and tool production patterns can be reasonably determined by examining lithic attributes on flakes from a larger debitage assemblage. Certain technology types that are a result of lithic production can be determined by examining the debitage. This information can be used to infer the activities that may have taken place at a site and duration of site occupation, all of which ultimately dictates toolstone procurement strategies. Several variables that are used to interpret reduction stage include: cortex amount, dorsal scar count, size class, percussion type (lipping, bulb of percussion, erailure), platform preparation, modified Sullivan and Rozen typology (Prentiss 2001), and flake type.

Cortex amount and dorsal scar count are two measures that are intimately tied to reduction patterns and very minimally affected by combinations of behaviors. Due to tool production being a reductive process, there are a minimal number of patterned results that can be produced from nodule reduction. For instance, an unmodified raw material nodule will have 100% cortex, and an early reduction stage flake will likely have >50% cortex, while later stage flakes will have little to no cortex because it was all removed in early stages. Conversely, dorsal scars increase in number throughout the reduction process.

Size measures of debitage assemblages can be indicative of reduction stage, assuming that smaller flakes are associated with later reduction stages (Andrefsky 2005). Instances where size may not only be an indication of reduction stage is when different technological forms are produced from varying nodule sizes (Andrefsky 2005). Regardless, in general, large flakes will be removed early in the reduction process and as the objective piece gets smaller, the subsequent detached flakes will also be smaller (Andrefsky 2005). Length as a measure of reduction stage can be confounded by flake breakage, therefore patterns of flake length can be compared to flake width, thickness, and weight which are less affected by post-depositional disturbances and equifinal causes.

Flake thickness is an attribute that indicates reduction stage at a site because later stage reduction cannot produce as thick flakes as early reduction when excess amount of material has been removed. Flake thickness may also be affected by raw material quality, nodule size and shape. The results of thickness class distributions in comparison of the site components follow the same general trend as the length and width classes.

The weight class distribution is another good indication of reduction based on distance to a raw material source, as well as the general reduction stage. In tandem with the other metric measures, lighter flakes are associated with late stage reduction and is probably the least biased measure to determine this based on different fractures and nodule size (Shott 1994, Andrefsky 2005). The results show a consistent pattern with the other metric measures. Further, it is often assumed in general terms of efficiency of material transport that lighter proportions of material will be found farther from a material source.

Platform type percent per site only includes broken and complete flakes, flakes that have a proximal end. Platform preparation may indicate stages of lithic reduction and type of tool production. Cortical platforms indicate the primary reduction stage of removing cortical surfaces of the objective nodule. Flat striking platforms, referred to as simple platforms are indicative of non-bifacial tool production, and are usually removed from unidirectional cores. Though, small flakes with platforms may have been removed from a smooth surface of a flake blank (Andrefsky 2005). Complex and abraded platforms are indicative of late stage tool production or more investment in material preparation. The facets on the complex platforms is associated with the number of flakes that were removed from the objective piece prior to the removal of the flake with a complex platform. Bifacial thinning flakes often have complex platforms. Abraded platforms also indicate a late stage of reduction and are thought to represent more time investment taken to ensure that the objective piece will flake in the desired way (Andrefsky 2005).

Proximal end attributes including bulb of percussion type, lipping presence or absence, and erailure scar presence or absence indicates the type of percussor and the force that was used to remove a flake. Soft hammer percussion, characteristic of tool re-sharpening and thinning, and tool preparation, is performed by hitting the objective piece with an antler tine. Hard hammer percussion, characteristic of reducing a toolstone nodule and removing cortex, and removing large flakes with less precision, is performed with a rock that is harder than the objective piece. Soft hammer percussion is recognized on flakes that has lipping with no erailure scars and salient bulbs of percussion are uncommon (Odell 2004). Alternatively, hard hammer percussion produces salient bulbs, erailure scars, but lipping is uncommon (Odell 2004).

Modified Sullivan and Rozen typology provides an avenue for interpreting technological characteristics from flake completeness, based on variation due to size (Prentiss 2001). High proportions of complete flakes have been shown to indicate tool production and specifically biface production (Andrefsky 2005). Complete flakes and proximal flakes also indicate tool reduction. Whereas, fragments of flakes are indicative of early reduction stages. Shatter is thought to often be associated with bipolar reduction techniques. Modified Sullivan and Rozen typology incorporates the flake size into the interpretation by testing flake breakage patterns based on the size of the detached piece (Prentiss 2001). However, it has also been argued that the Modified Sullivan and Rozen method lacks accuracy and the “interpretation-free” method of analysis should not be performed without other lines of evidence (Odell 2004).

Flake type refers to classifying detached pieces of lithic debitage in terms of the stone technology that was ultimately produced, in turn creating the specific flaking pattern. Some of these technological types include bifacial thinning flakes, bipolar flakes, retouch scraper flakes, etc. These technological classifications have been critiqued by Sullivan and Rozen (1985) but their determination with other lines of evidence from independent attribute measures on the flake may provide better grounds for classifying debitage into technological types. On one hand, fairly universal distinguishing features of bifacial thinning flakes and bipolar flakes make them easily recognizable and not likely to be misclassified (Andrefsky 2005). However, adding detail in technological types to forms that are less easily recognized may be problematic due to the similarity between small flakes with simple platforms associated with multiple technological types (Andrefsky 2005).

XMH-35 Residential Site

XMH-35 has a similar distribution of flakes with and without cortex as Whitmore Ridge C2, in that there are robust proportions of flakes with no cortex (84.8%), flakes with less than 50% cortex (12.7%) and flake with 50% or more cortex (2.5%) (Table 5.11). From the cortex data alone, it may be inferred that the reduction strategies are similar at both Whitmore Ridge C2 and XMH-35, suggesting a variety of tool production and core reduction through multiple occupations.

The dorsal scar counts on the flakes in the sample from XMH-35 clearly reaffirm the patterns recognized from the cortex amounts. The highest proportion of the XMH-35 sample is made up of flakes with more than 4 dorsal scars (36.4%) which is typical of bifacial thinning flakes (Table 5.11). High numbers of dorsal scars are also distinguishing of late stage reduction because more flakes are often removed later in the process of reduction for tool production. The smallest proportion of flakes at XMH-35 have 0 dorsal scars (6.7%) and 1 dorsal scar (3.7%), (Table 5.11).

The flakes with proximal ends in the XMH-35 debitage sample have a higher proportion of abraded platforms (25.7%) than simple platforms (20.7%) (Table 5.11). There was an even higher proportion of complex platforms at this site (37.9%), and the lowest proportion of cortical platforms (4.3%) compared to all the other Northern Archaic sites (Table 5.11). The presence of complex platforms indicates tool maintenance, likely bifacial maintenance. Then the high proportion of abraded platforms in addition to complex platforms suggests time investment in tool production rather than early stage reduction.

XMH-35 has the highest proportion of broken and complete flakes of the Northern Archaic site components in this study. The percent of complete flakes (28.4%) at XMH-35 was the closest to the percent of flake fragments (27.2%) (Table 5.11). This indicates that tool reduction was taking place at this site, as well as tool production, specifically biface production. It is also the only site that has shatter (0.8%), which provides evidence for the variety of techniques used to produce tools and reduce material at XMH-35.

XMH-35 does not have any flakes within the last 10 longest length classes (Figure 5.10). There are also no flakes in the smallest size class (Figure 5.10). However, 63.6% of the flakes in the XMH-35 sample are in size classes four through 7 (Figure 5.10). Because XMH-35 has a high proportion of complete flakes, the lack of long flakes is more likely a result of late stage tool production and material conservation.

The width class shows a similar distribution as the length class for all the sites. Which indicates that variation in length is not necessarily biased by high proportions of flake fragments and broken flakes (Figure 5.11).

The sample of the XMH-35 assemblage has very high proportions of thickness classes three and four, totaling 53.9%, and most of the material is thin (Figure 5.12). The assemblage does not have any flakes that are in thickness classes from 14 through 21 (Figure 5.12). This provides more evidence for late stage tool production and maintenance occurring at XMH-35.

The XMH-35 assemblage has an extreme positive skew towards light flakes (Figure 5.13). XMH-35 has no flakes heavier than weight class 10, while 68.3% of flakes are in the lightest weight class (Figure 5.13). The weights of the flakes in the XMH-35 sample primarily indicates late stage reduction and tool production.

XMH-35 has a higher proportion of flakes with erailure scars (Table 5.11), no lipping (Table 5.11), and diffuse bulbs (Table 5.11). Since salient bulbs seem to be absent in some cases with flakes with erailure scars and lipping absence, this assemblage has been produced with both soft and hard hammer percussion.

XMH-35 showed the most variation in technologic types based on the attributes of the debitage sample, including bipolar flakes (1.2%), core parts (0.7%), decortication flakes (4.2%), bifacial thinking flakes (14.5%), shatter (0.5%), and simple flake (78.8%) (Table 5.11). Other than simple flakes, bifacial thinning flakes occur in high proportions. The site has the smallest proportion of decortication flakes compared to the other Northern Archaic sites (Table 5.11). This suggests that tool maintenance is a main but not the only activity that occurred at the site. Core reduction, and tool production also took place. XMH-35 on the other hand, has the highest proportion of bipolar flakes and bifacial thinning flakes and the lowest proportion of decortication flakes (Table 5.11), indicating later stage reduction, bifacial tool production, and material conservation.

Landmark Gap Trail Site

Of the Northern Archaic components, the Landmark Gap Trail site yielded the highest proportion of flakes with cortex: 23.1% with less than 50% cortex, and 1.5% of the sample with greater than 50% cortex (Figure 5.2.1). Subsequently, it has the lowest proportion of flakes with no cortex compared to the other components (75.4%) (Table 5.11). While this clearly indicates flakes with no cortex dominate the site assemblage, the relatively high proportion of flakes with cortex compared to the other Northern Archaic components may indicate a tendency toward more early stage reduction at this site.

The Landmark Gap Trail site has a high proportion of flakes with more than 4 dorsal scars (31.3%), then also fairly high proportions of flakes with two (19.1%) and three (20.6%) dorsal scars (Table 5.11). The proportion of flake with no dorsal scars (10.4%) falls is somewhere between the proportion of flakes with no dorsal scars from Whitmore Ridge C2 (23.5%) and XMH-35 (6.7%), (Table 5.11). The relatively high proportion of flake with more than four, two and three dorsal scars in comparison to a smaller proportion of flakes with no dorsal scars is somewhat surprising considering that the site also had the highest proportion of flakes with cortex compared to the other assemblages. However, it does indicate multiple reduction stages occurring at the site from early stage reduction through tool production. However, it is difficult to tease out if there was specialization of activity associated with tool maintenance as opposed to generally producing tools by reducing nodules at the site.

Landmark Gap Trail site has the highest proportion of cortical platform flakes (7.2%) than the other Northern Archaic components; however, this proportion is small compared to the proportions of complex platforms (39%), simple platforms (27.4%), and abraded platforms (19.5%), which indicates all stages of core reduction to tool production taking place at the site (Table 5.11).

The flake completeness categories for the Landmark Gap Trail assemblage show close to equal proportion of broken flakes (39.5%) and fragments (40.5%), (Table 5.11). Therefore, the proportion of flake fragments far exceed that the proportion of fragments at XMH-35. However, the proportion broken and complete flakes together (52.1%) exceeds the proportion of fragments, thus indicating tool production (Table 5.11). The high proportion of fragments cannot be ignored as it also indicates early stages of reduction occurring at the site.

The Landmark Gap Trail Site differs from the other Northern Archaic components in that is has much more representation of the longer size classes (7.9% in the longest 10 size classes) but about the same proportion of complete flakes as Whitmore Ridge C2 (Figure 5.10). This pattern could indicate the use of larger nodules depending on the raw material type, or that early and late stage reduction is present at this site. Landmark Gap Trail Site has the widest distribution of flake lengths, such that 62.8% of the sample is within size classes four through 10 (Figure 5.11).

This assemblage has a much lower proportion of thin to thick flakes, such that the distribution from thin to thick is wider than the other two Northern Archaic components, suggesting a more even balance between early and late stage reduction (Figure 5.12). There are flakes in every thickness class except for the thinnest class and the thickest class. (Figure 5.12). The distribution is still positively skewed towards thin flakes such that 55.3% of the flakes in the sample fall into the size classes two through six (Figure 5.12).

The distribution of flake weights has a positive skew towards light weights, but flakes fall into all weight classes except for classes 14, 22, and 25 (Figure 5.13). 3.2% of the sample is in the heaviest class (Figure 5.13). 66.7% of the flakes are in the lightest three weight classes (Figure 5.13). This site shows evidence for tool production and late stage reduction but more even focus on early reduction stages.

Of the three Northern Archaic components, Landmark Gap Trail Site had higher proportions of salient bulbs of percussion (Table 5.11) and presence of erailure scars (Table 5.11) which may indicate more use of hard hammer percussion. This interpretation is consistent with both early and late stage reduction taking place at this site in a more even manner than the other two Northern Archaic sites.

Landmark Gap Trail site has the least variation in technological types compared to the other Northern Archaic components. Decortication flakes (17.4%) are proportionally highest at the Landmark Gap Trail site, but the site also has the lowest proportion of bifacial thinning flakes (2.0%), and no bipolar flakes (Table 5.11). Core parts make up 0.5% of the sample (Table 5.11). This indicates more apparent early stage core reduction, no signs of material conservation, and focus on expedient tool production in contrast to very little biface maintenance.

Whitmore Ridge C2

Whitmore Ridge C2 has the greatest proportion of flakes without any cortex (88.1%) compared to the other components (Table 5.11). However, it maintains proportions of both flakes with less than 50% cortex coverage (9.4%) and greater than 50% cortex (2.5%), (Table 5.11). The presence of differing amounts of cortex on the flakes in the Whitmore Ridge C2 sample indicate all reduction stages from early to late stage tool production, with a dominance of late stage tool reduction.

This component has distinctly different distribution of flakes with dorsal scars than the other Northern Archaic components (Table 5.11). It has the highest proportion of flakes with no dorsal scars (23.5%) and the lowest proportion of flakes with greater than four dorsal scars (13.2%), (Table 5.11). The pattern of dorsal scar presence from this sample highlights multiple reduction stages including likely early core reduction occurring at the site, through tool production.

The Whitmore Ridge C2 sample has the highest proportion of simple platforms (33.6%) and also the highest proportion of complex platforms (42.5%) of the Northern Archaic sites (Table 5.11). Cortical platforms occur in 6.5% of the Whitmore Ridge C2 sample (Table 5.11). The high proportion of complex platforms in comparison to abraded platforms (14%) may indicate tool maintenance and bifacial tool maintenance is occurring at the site in addition to early and late stage reduction and tool production (Table 5.11). The technological types will add to the understanding of platform types.

This component also has the highest proportion of flake fragments (46.6%) and lowest proportion of broken and complete flakes combined (50.1%) than the other Northern Archaic components (Table 5.11). However, the amount of broken and complete flakes still exceeds the amount of flake fragments. Similar to MH-289, it is likely that tool production was occurring at this site but there may have been more of a focus on early reduction as well.

Only 1.3% of the flakes from the Whitmore Ridge C2 sample are in the longest 10 length classes (Figure 5.10). Whitmore Ridge C2 has high proportions of broken flakes and flake fragments which could be the cause of 8.4% of the sample falling within the first two length classes and 62.8% of flakes within length classes three through six (Figure 5.10).

50.4% of the Whitmore Ridge C2 sample is within thickness classes three and four (Figure 5.12). Whitmore Ridge C2 has representation in every thickness class except for 14 and 20, though the percentages of flakes with a thickness from 14 – 21 is low, totaling 3.0% (Figure 5.12) Therefore, the site likely has late stage reduction and tool production at the site, as well as some early stage reduction, which may be material dependent.

Whitmore Ridge C2 has a very low proportion of heavier flakes, such that classes five through 27 total 4.8% of all the sample, even though oddly 0.8% of this proportion is in the heaviest weight class (Figure 5.13). However, 79.5% of the flakes in the sample are in the lightest weight class (Figure 5.13). MH-72 C2 is oriented towards late stage reduction and tool production, though there may have been several instances of tool production.

Whitmore Ridge C2 has a higher proportion of flakes with erailure scars (Table 5.11), no lipping (Table 5.11), and diffuse bulbs (Table 5.11). Two out of the three of these variables are consistent with hard hammer percussion. Salient bulbs are an indicator of hard hammer percussion, so it is likely that both forms of percussion likely occurred at the site but there is not a clear pattern indicating one or the other.

The debitage sample from Whitmore Ridge C2 also includes all of the technological types that were recorded in the study. The distribution of flake types is similar to that of XMH-35 but there higher proportions of shatter (6.3%) and decortication flakes (4.8%), but a lower proportion of bipolar flakes (0.3%) and bifacial thinning flakes (2.8%) (Table 5.11). Therefore, tool production and core reduction took place at the site; however, there may have been less of a focus on bifacial tool maintenance.

Whitmore Ridge C1

The Denali Component (Whitmore Ridge C1) has less than 1% of the assemblage with cortex that is greater than 50% of the sample (Table 5.11). Notable comparison between the Denali component at Whitmore Ridge and the Northern Archaic component at Whitmore Ridge is that the earliest stage of reduction based on cortex amount is not well represented during the Denali component.

Whitmore Ridge C1 and Whitmore Ridge C2 have very different distributions of dorsal scar counts (Table 5.11). Component 1 has a very high proportion of flakes with a dorsal scar count greater than four (42.7%), (Table 5.11). Subsequently, there is a small proportion of flakes with no dorsal scars

(7.2%) (Figure 5.2.2). The distinct difference between Whitmore Ridge C1 and C2 could be an indication of equifinality in the variation of technology. The difference could be a result of time, site type, or procurement strategies. Patterns identified in the use of different raw materials at each site could tease out this palimpsest.

Whitmore Ridge C1 has a large proportion of complex platforms (52.2%), as well as almost equal proportions of abraded (18.9%) and simple platforms (19.4%), which is clearly different from the Northern Archaic component (Table 5.11). This suggests a focus on late stage tool production and reduction, though early stage reduction also occurred due to the presence of cortical platforms (6%), but was less of the focus (Table 5.11). The difference in late stage production and early stage reduction may be a result of raw material type, and will be addressed in the following sections.

Whitmore Ridge C1 differs slightly from Whitmore Ridge C2 in that it has a slightly lower proportion of flake fragments (42.2%) and higher proportion of broken flakes (40.2%) (Table 5.11). The close proportions of fragments and broken flakes suggests that early stages of reduction were occurring at the site as well as tool production.

The distribution of flake lengths is very different between component 1 and component 2 at Whitmore Ridge. Component 1 has a very wide distribution of flake lengths such that 62.8% of the sample falls within length classes three through 13 (Figure 5.10). This component has high proportion of flakes within the longest 10 length classes (12.4%) (Figure 5.10). While Whitmore Ridge C1 has indicated all the signs for tool production and late stage reduction, along with a lesser focus on early stage reduction, it is surprising to see the most long flakes in this component. However, this may be an indicator of a difference in raw material package size and type.

The distribution of flake thickness at Whitmore Ridge C1 is wider across all thickness classes than component 2, suggesting a relatively even focus on early and late stage reduction. There are flakes within every thickness class except for the thinnest and thickest classes. The distribution is positively skewed towards thinner flakes. The thickness class with the highest proportion of flakes is class three (16.4%), (Figure 5.12).

The weight distribution for the Whitmore Ridge C1 sample show clear patterning for early reduction stages complimenting some later reduction stages. It is very different from the Whitmore

Ridge C2 component, in that it has a much wider distribution of flakes in all weight classes (Figure 5.2.8). There is not a single weight class that is not represented, though there is a positive skew toward lighter weight classes (Figure 5.13). 5.2% of the sample is in the heaviest weight class and 52.9% of the sample is in the lightest three weight classes (Figure 5.13).

Whitmore Ridge C1 has a higher proportion of erailure scar absence (Table 5.11), lipping absence (Table 5.11), and diffuse bulbs of percussion (Table 5.11), compared to the Northern Archaic components. Specifically, the Denali component has approximately the same proportion of lower lipping presence as the others, but much higher proportions of erailure scars and salient bulbs of percussion. This indicates that hard hammer percussion was used more readily with soft hammer percussion in the Denali component than the Northern Archaic components.

Finally, Whitmore Ridge C1 has distinct differences in variety of types present as compared to Whitmore Ridge C2. The marked differences include the presence of decortication flakes (15.4%) in the Whitmore Ridge C1 sample (Table 5.11). Then also, the lack of bifacial thinning flakes (1.5%), indicating that biface production and maintenance were less important in the Denali components (Table 5.11).

Table 5.11 Lithic attributes recorded on lithic debitage from each component. The percent of total debitage sample from each component with particular attributes was calculated.

Attribute		% of Whitmore Ridge C1	% of Whitmore Ridge C2	% of Landmark Gap Trail Site	% of XMH-35
cortex amount	none	78.4	88.1	75.4	84.8
Cramer's V-square 0.01	0-50%	21.1	9.4	23.1	12.7
	>50%	0.5	2.5	1.5	2.5
dorsal scar count	0	7.2	23.5	10.4	6.7
Cramer's V-square 0.04	1	5.5	9.1	5.5	3.7
	2	13.7	24.6	19.1	15.5
	3	16.9	21.5	20.6	18.7
	4	14.1	8.1	13.2	19.0
	>4	42.7	13.2	31.3	36.4
platform type	abraded	19.0	14.0	19.5	25.7

Cramer's V-square 0.02	complex	52.2	42.5	39.0	37.9
	cortical	6.0	6.5	7.2	4.3
	crushed	3.5	3.3	6.8	11.4
	simple	19.4	33.6	27.5	20.7
Sullivan and Rozen typology Cramer's V-square 0.02	broken	40.2	34.2	39.5	40.9
	complete	14.4	16.0	22.7	27.2
	fragment	42.2	46.6	40.5	28.4
	shatter	0	0	0	0.8
	split	3.2	3.3	7.4	2.7
flake type Cramer's V-square 0.05	bifacial thinning	1.5	2.8	2.0	14.5
	bipolar	0	0.3	0.3	1.3
	core part	0.7	0.5	0.5	0.8
	decortication	15.4	4.8	17.4	4.2
	modified flake	0	0.8	0	0
	shatter	0	6.3	0	0.5
	simple	82.4	84.6	79.9	78.8
erailure scar Cramer's V-square 0.03	present	43.3	19.6	68.2	62.6
	absent	56.7	80.4	31.8	37.4
lipping Cramer's V-square 0.01	present	25	24.3	30.4	33.2
	absent	75	75.7	69.6	66.8
bulb of percussion Cramer's V-square 0.03	salient	15.9	33.6	21.7	14.8
	diffuse	84.1	66.4	78.3	85.2

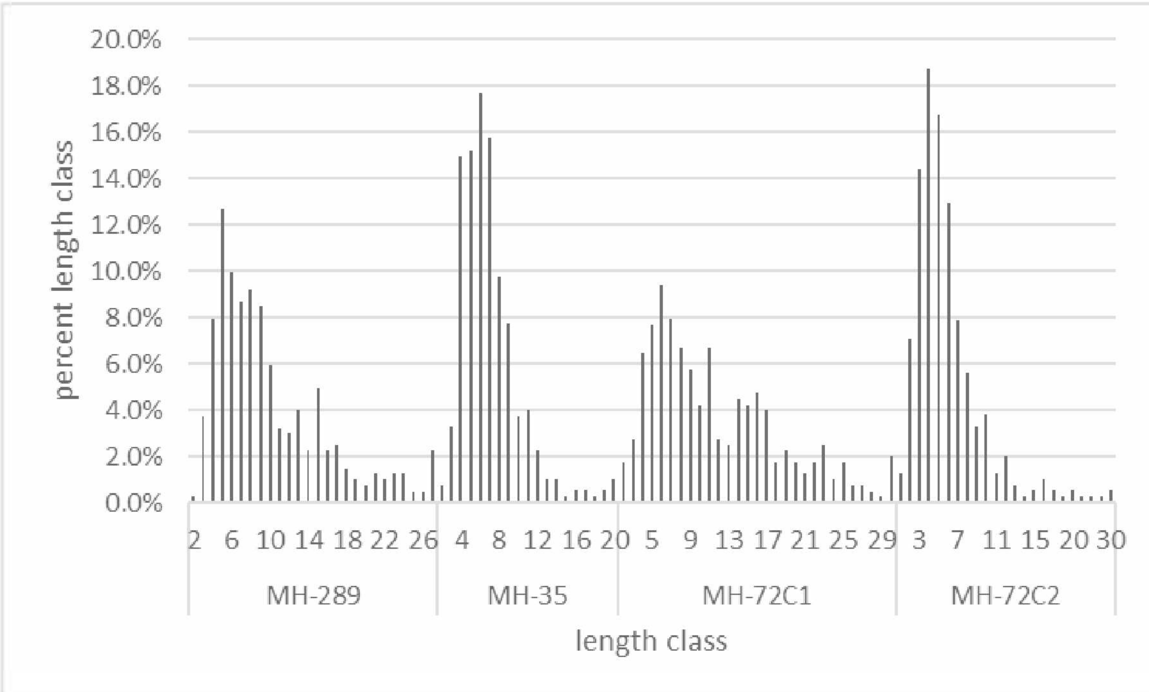

Figure 5. 10 Distribution proportions of artifacts assigned to length classes at each site. Cramer's V-square = 0.10.

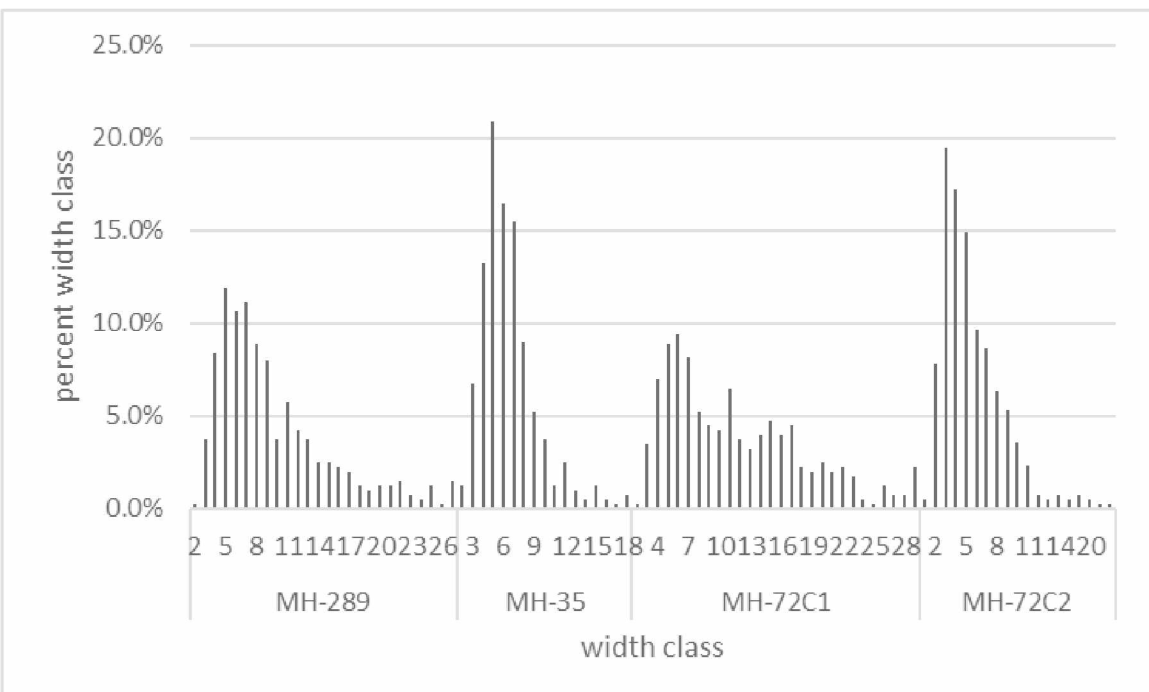

Figure 5. 11 Distribution proportions of artifacts assigned to width classes at each site. Cramer's V-square = 0.11

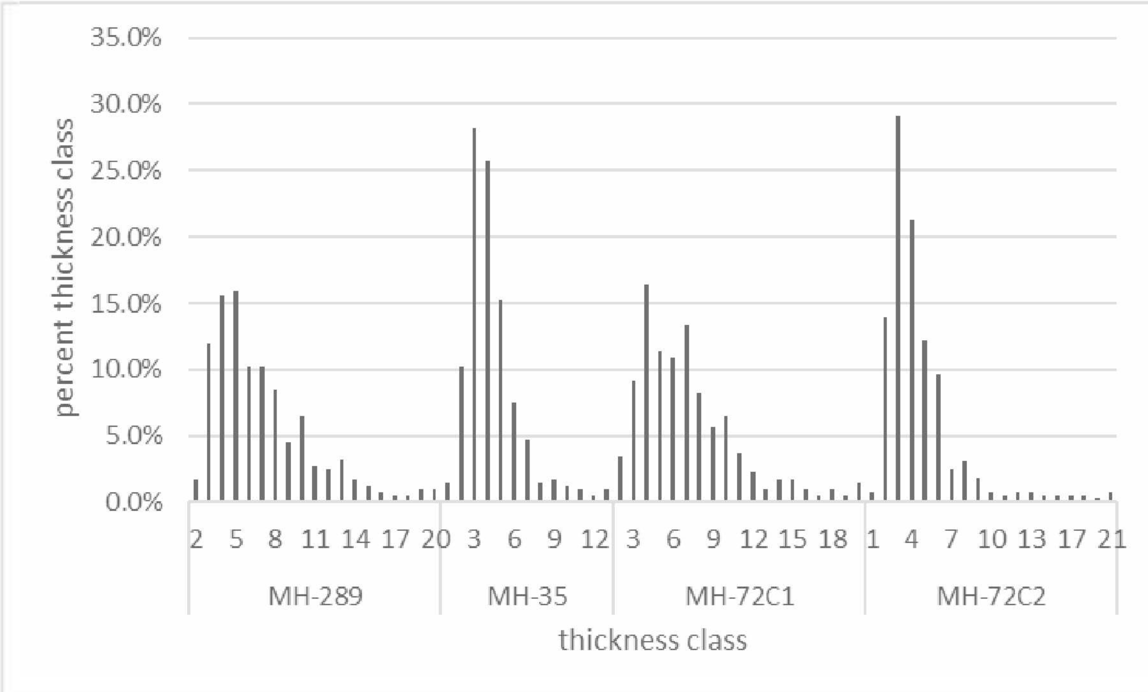

Figure 5.12 Distribution proportions of artifacts assigned to thickness classes at each site. Cramer's V-square = 0.07

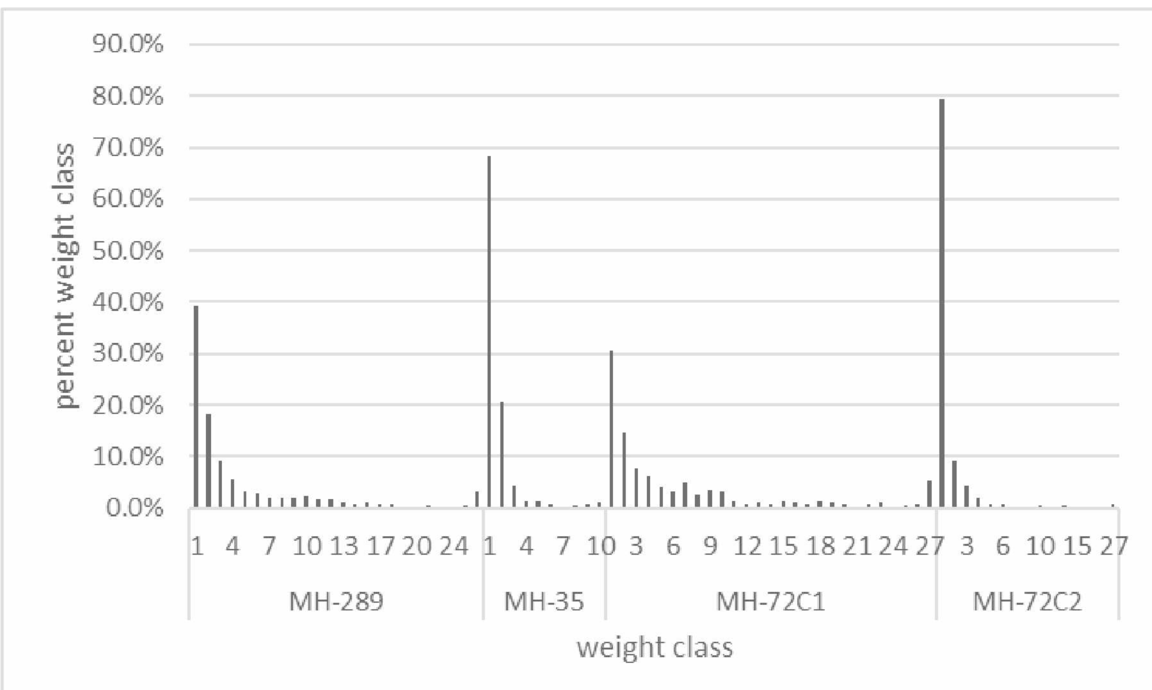

Figure 5. 13 Distribution proportions of artifacts assigned to weight classes at each site. Cramer's V-square = 0.08

Trends Across All Components

All sites showed the highest proportion of technology represented as simple flakes. Ultimately, XMH-35 and Whitmore Ridge C2 showed the most variation in technological types of the Northern Archaic components. Early stage core reduction and tool production seem to be the main activities at The Landmark Gap Trail Site (Table 5.12). Biface maintenance and additional tool production activities are apparent at XMH-35 (Table 5.12). Similarly, tool production was a focus of Whitmore Ridge C2 and less bifacial maintenance than XMH-35, rather expedient tool production and maintenance (Table 5.12). The Denali Component a major focus on core reduction and expedient tool production, and the most minimal bifacial maintenance (Table 5.12).

The majority of all the component samples are made up of flakes that do not have proximal ends and platforms. Of the sample that have platforms (proximal and complete flakes) complex platforms are the most common across all components but particularly for Whitmore Ridge during both the Denali component and the Northern Archaic component. Of the Northern Archaic components, each site is similar. However, the most apparent pattern deviation is in the XMH-35 assemblage such that there is a higher proportion of abraded platforms than simple platforms, whereas all the other Northern Archaic component's second highest proportion of flakes had simple platforms.

The patterns between the sites based on the proximal end attributes associated with percussion type indicate a shift in use of percussion type through time and slight differences possible within the Northern Archaic components based on site type. To begin with the Northern Archaic site component samples, all the sites displayed a higher proportion of erailure absence and diffuse bulbs of percussion, but more flakes without lipping. However, the lipping presence was similar for all the Northern Archaic sites. The high proportion of diffuse bulbs with no erailure scars and relatively even proportions of lipping presence indicates soft hammer percussion dominated this component.

Cortex amount and dorsal scar count are relatively strong indicators of reduction stage. All components are dominated by assemblage samples that contain flakes with no cortex. All three Northern Archaic components have over 50% cortex that are over 1% of each sample, while the Denali Component (Whitmore Ridge C1) has less than 1% of the assemblage with cortex that is greater than 50% of the sample. Further, all of the components have less than 30% of the assemblage with 1 – 50% cortex. Notable comparison between the Denali component at Whitmore Ridge C1 and the Northern

Archaic Component of Whitmore Ridge C2 is that the earliest stage of reduction based on cortex amount is not well represented during the Denali component at the site but all stages are represented in the Northern Archaic component.

The first most apparent and consistent pattern is XMH-35 being a tool production site marked by late stages of reduction, but also showing signs of early stage nodule reduction. This site has the most variation in the technologies that were employed based on the aggregate analysis of debitage flake type. The cortex presence on artifacts at XMH-35 indicate that all stages of reduction, including minimal amounts of early stage reduction occurred at the site, but the site was dominated by late stage reduction. This same pattern is clearly apparent based on the dorsal scar count, Sullivan & Rozen typology considering size and metric measures, the proximal end attributes, and the platform type. The platform type also indicated that a significant amount of time was invested in preparing the platforms, suggesting planned tool production.

The other two sites associated with the Northern Archaic component had fewer extreme indicators of early or late stage reduction but the Landmark Gap Trail site stood out as having an opposite pattern to XMH-35, such that the interpretation of the attributes as a whole suggested a tendency towards early stage reduction but also the presence of tool production. It is likely that all stages were present at the site but toolstone was also being reduced there in higher quantities than the other sites. Most of the reduction process was being carried out at this site, but formal tools were likely reduced more and/or used offsite. Finally, Whitmore Ridge C2 has the most even representation of both early and late stage reduction. The cortex amount and the flake type at Whitmore Ridge C2 indicate all stages of reduction and a variety of technological types produced at the site. The flake completeness variable also indicated both tool production and early stage reduction at the site. On the other hand, while dorsal scar count and platform type indicated all levels of reduction and tool production, those variables alone would suggest more focus on early stage reduction. However, all the metric attributes indicated that early and late reduction stages occurred but suggested more of a focus on late stage reduction.

The lithic attributes as a whole in the Denali Component at Whitmore Ridge suggested that both early and late stage reduction and tool production was occurring at this site. However, all the qualitative attributes (cortex amount, flake type, dorsal scar count, platform type, and flake completeness) suggest the late stage reduction and tool production was the main activity at the site, with distributions of the variable frequencies most comparable to the Northern Archaic component at XMH-35. Alternatively, the metric measures (length class, width class, thickness class, and weight class) all indicate that early stage reduction was the main activity at the site, such that the distribution of metric attribute frequencies is most similar to Landmark Gap Trail Site. The proximal flake attributes (erailure scar, lipping, and bulb of percussion) indicate that both soft hammer and hard hammer percussion were taking place at this site, however the proportion of indicators of hard hammer percussion being used was much higher than all the other components.

The documented tools from each site reaffirm the generalized activities that are inferred from the debitage technological types (Table 5.12) and the site descriptions in previous literature about the sites (Table 5.13). These patterns are most apparent by the variation and number of certain tools. The Denali component at Whitmore Ridge is dominated by microblade technology but completely lacks much bifacial, unifacial, and blade technology (Table 5.14). Alternatively, the Northern Archaic component at Whitmore Ridge has much more variation in technology including bifaces, blades, unifaces, burins, a modified flake, and a much lesser amount of microblades (Table 5.14). Of the Northern Archaic components XMH-35 has the most bifaces, coupled by several modified flakes and unifaces (Table 5.14). Finally, Landmark Gap Trail Site Feature 1, has the least tool variation with only bifacial technology remaining and possibly a modified flake. Therefore, the proportions of bifacial thinning flakes to bifacial tools and tool parts in each site component seems consistent for the technological assumptions being made (Table 5.15).

Table 5.12 Summary of activities associated with the debitage analysis of each component in the study.

	Whitmore Ridge C1	Whitmore Ridge C2	Landmark Gap Trail Site	XMH-35
Cortex amount	More Late stage reduction, some early stage	All stages of reduction	All stages of reduction	All stages of reduction
Flake type	Early stage decortication, microblade tech., least (biface thinning) tool maintenance	Variation in technology production, and biface maintenance	Early stage core reduction, tool production and some biface maintenance	Variation in technology production, bipolar reduction – possible material conservation, biface maintenance
Dorsal scar count	More late stage reduction and tool production	Early stage reduction and less late stage	All stages of reduction, more early core reduction, less late stage	Late stage reduction, and tool maintenance
Platform type	More late stage reduction and tool production	All stages of reduction	All stages of reduction	Late stage reduction, time investment in tool production
Sullivan & Rozen Typology	Tool production and early stage reduction	Tool production and early stages of reduction	Tool production and early stages of reduction	Late stage reduction, tool production and maintenance
Length Class	All reduction stages, including early stages	All stages of reduction, some late stage (fragment bias)	All stages of reduction, more early stage	Late stage reduction (less fragment bias)
Width Class	All reduction stages, including early stages	All stages of reduction, some late stage	All stages of reduction, more early stage	Late stage reduction

Thickness Class	All reduction stages, including early stages	All stages of reduction, more late stage, less early stage	All stages of reduction	Late stage reduction
Weight Class	All reduction stages, including early stages	All stages of reduction, more late stage, less early stage	All stages of reduction	Late stage reduction
Erailure (presence/absence)	Soft and hard hammer percussion, possibly more hard hammer	More soft hammer percussion	Soft and hard hammer percussion, possibly more hard hammer	More soft hammer percussion
Lipping (presence/absence)				
Bulb of percussion				

Table 5.13 Site descriptions from previous excavations and associated literature.

Site	Activity Type in literature
Whitmore Ridge C1	Bifacial thinning activities, preferential core and blade activities (West et al. 1996).
Whitmore Ridge C2	Preferential use of core and blade technology. Short term activity associated with repeated activities performed at the site over a short period of time (West et al. 1996)
MH35 Level3 Sample	Residential site with house and hearth features; intensely occupied during Mid-Holocene; Northern Archaic notched point production (Robinson 2003).
Landmark Gap Trail Site Feature 1	Single event at a site that was repeatedly and heavily occupied. Tool manufacture and large game lookout. Tool production, minimal maintenance. Multipurpose campsite (Mobley 1982).

Table 5.14 Tools recorded from site components/feature in the study based on accession catalogs.

Site	Blade Core	Microblade	Microblade Core	Modified Flake	Small Blade	Biface	Blade	Burin	Uniface	Total
Whitmore Ridge C1		36	12	1	18					67
Whitmore Ridge C2	18	8	1	5	69	2	8	2	7	120
MH35 Level3 Sample				2		6			2	10
Landmark Gap Trail Site Feature 1				1		4				5

Table 5.15 Associated bifacial debitage to bifacial tool ratio from the site components in the study.

Site	Bifacial Thinning	Bifacial Thinning %	Bifacial Tool or Part	Total Bifacial Technology
Whitmore Ridge C1	6	1.5	0	6
Whitmore Ridge C2	11	2.8	2	13
MH35 Level3 sample	58	14.5	6	64
Landmark Gap Trail Site Feature 1	8	2.0	4	12

5.8 Estimated Local and Non-local Materials

The Niton analysis of the assemblages only extended to the debitage of appropriate size, thickness, and flatness for ED-pXRF analysis on the Niton. Therefore, a sub-sample of flakes from lithic assemblages that were chemically analyzed is assumed to represent the variation/distribution of the materials (Landmark Gap Quarry material, Long Tangle Lake Quarry material, and unknown material) in the four component assemblages. The sub-sample is considered to appropriately encompass the behavioral variation in attributes of the debitage, as small artifacts tend to lack diagnostic attributes for interpreting behavior. The Niton analysis of the artifacts provided definitive results of their origins. There were 127 artifacts assigned to the Landmark Gap Quarry, 143 were assigned to the Long Tangle Lake Quarry, and finally 288 were assigned to an unknown group. The unknown group could represent multiple unknown toolstone sources. Sorting the assigned artifacts into their associated groups (XMH-35: Long Tangle Lake Quarry, Landmark Gap Quarry, and Unknown; Whitmore Ridge Component 1: Long Tangle Lake Quarry, Landmark Gap Quarry, and Unknown; Whitmore Ridge Component 2: Long Tangle Lake Quarry, Landmark Gap Quarry, and Unknown; Landmark Gap Trail Site: Long Tangle Lake Quarry, Landmark Gap Quarry, and Unknown) demonstrates undisputable evidence for the lack of ability to visually source these common toolstone materials as there is significant visual overlap between the known sourced artifacts and the assigned unknowns (Figure 5.14, Figure 5.15).

As discussed in Chapter 4, the assigned unknown and the unassigned unknown materials required regrouping in to estimated local and non-local material groups. Of the 22 raw material codes that were represented within the assigned unknowns, 10 are estimated to be local and 12 are estimated to be non-local (Table 5.16). These groupings were used as an additional level of evidence to reinforce the estimation of local and nonlocal material of the unassigned unknown artifacts. It is possible that a proportion of these unassigned unknown flakes are made of Landmark Gap Quarry or Long Tangle Lake Quarry material. The same variables were used to estimate local and non-local groups with additional variables such as the number of artifacts of the raw material group assigned to a quarry, the raw material code corresponds with a raw material code assigned to local or nonlocal based on the assigned unknowns, number of flakes per raw material group in each component, and total debitage count and percent for each raw material code. Based on these variables 39 raw material codes were sorted into local and non-local groups, where 15 are estimated to be local and 24 were estimated to be nonlocal (Table 5.17). For the subsequent lithic behavioral analysis the best and most appropriate scale of raw material assignment was applied to the lithic debitage, such that all artifacts that were assigned to one of the two quarries are referred to by their actual material type, whereas the other are only referred to as local or nonlocal because that is the most precise scale that can be incorporated without providing false data and retaining significance for behavioral analysis. The scale of local and non-local is useful for inferring extent of mobility and general procurement strategies (Odell 2004).

Figure 5.14 Comparison of materials of selected artifacts from the Whitmore Ridge C1 assemblage. The rows represent material compositionally assigned to the same source. The top row is all material from Landmark Gap Quarry. The middle row is all material from the Long Tangle Lake Quarry. The bottom row consists of materials assigned to unknown sources.

Figure 5.15 Comparison of materials of selected artifacts from the XMH-35 assemblage. The rows represent material compositionally assigned to the same source. The top row is all material from Landmark Gap Quarry. The middle row is all material from the Long Tangle Lake Quarry. The bottom row consists of materials assigned to unknown sources.

Table 5.16 Local and non-local estimations of flakes that were compositionally assigned to the group of unknown sources.

Material Assigned Unknowns	Number of flakes	% flakes sampled	N with cortex	% with cortex	n<4 dorsal scars	% n<4 dorsal scars	> 2.5cm	> 2.5cm %	Estimated Local/Non-local Class
A1	172	59.7	33	19.2	70	40.8	94	54.7	Local
M2	20	6.9	1	5	7	35	4	20	Local
M1	17	5.9	4	23.5	12	70.6	3	17.6	Local
M3	13	4.5	1	7.7	3	23.1	8	61.5	Local
B4	13	4.5	3	23.1	5	38.5	2	15.4	Local
A19	12	4.2	2	16.7	6	49.9	5	41.7	Local
R1	7	2.4	1	14.3	6	85.7	2	28.6	Local
M4	6	2.1	1	16.7	2	33.4	1	16.7	Local
A2	5	1.7	0	0	1	20	4	80	Local
S1	1	0.3	1	100	1	100	0	0	Local
C2	6	2.1	1	16.7	3	50	0	0	Nonlocal
C1	3	1	0	0	1	33.3	0	0	Nonlocal
M5	2	0.7	0	0	0	0	1	50	Nonlocal
Q3	2	0.7	0	0	0	0	0	0	Nonlocal
S2	2	0.7	1	50	1	50	2	100	Nonlocal
B3	1	0.3	0	0	0	0	0	0	Nonlocal
C23	1	0.3	0	0	0	0	0	0	Nonlocal
C24	1	0.3	0	0	0	0	1	100	Nonlocal
M9	1	0.3	0	0	0	0	0	0	Nonlocal
Q1	1	0.3	0	0	1	100	0	0	Nonlocal
Q4	1	0.3	0	0	1	100	0	0	Nonlocal
S3	1	0.3	0	0	0	0	0	0	Nonlocal

Table 5.17 Local and non-local material estimations for the debitage that was not analyzed by the Niton, and are considered unassigned unknowns.

Unassigned Unknowns	# assigned to quarry	corresponds with assigned unknowns	# in MH72 C1	# in MH72 C2	# in MH35	# in MH289	debitage total	% debitage sampled	n with cortex	% with cortex w/in quarry	n<4 dorsal scars	%dorsal scar	> 2.5cm	> 2.5cm %	Local/Non-local Class
A1	124	Y	226	82	5	157	470	45	103	21.9	271	0.6	123	26.2	Local
M2	14	Y	3	72	16	0	91	8.7	10	11.0	73	0.8	3	3.3	Local
M1	3	Y	0	73	9	2	84	8	4	4.8	70	0.8	4	4.8	Local
M3	28	Y	9	9	30	0	48	4.6	10	20.8	31	0.6	4	8.3	Local
A19	7	Y	5	0	0	31	36	3.4	6	16.7	29	0.8	2	5.6	Local
A2	9	Y	5	2	3	17	27	2.6	6	22.2	12	0.4	8	29.6	Local
M4	13	NA	1	4	0	21	26	2.5	7	26.9	18	0.7	5	19.2	Local
S1	4	Y (low sample)	4	5	9	1	19	1.8	3	15.8	12	0.6	2	10.5	Local
B1	3	NA	1	1	9	0	11	1	5	45.5	9	0.8	2	18.2	Local
B3	2	N (low sample)	0	0	12	0	12	1.1	1	8.3	5	0.4	1	8.3	Local
B4	13	Y	2	31	41	0	74	7.1	6	8.1	52	0.7	0	0	Local
R1	2	Y	0	29	1	0	30	2.9	4	13.3	26	0.9	0	0	Local
C1	18	M (low sample)	1	1	28	0	30	2.9	4	13.3	16	0.5	0	0	Local
M5	22	N (low sample)	0	0	22	0	22	2.1	5	22.7	13	0.6	0	0	Local
Q3	2	N (low sample)	0	0	8	0	8	0.8	2	25.0	6	0.8	0	0	Local
M9	0	N (low sample)	0	0	6	0	6	0.6	0	0	2	0.3	0	0	Non-local
S2	0	M (low sample)	0	0	6	0	6	0.6	2	33.3	3	0.5	0	0	Non-local
C2	2	Y	0	0	5	0	5	0.5	0	0	2	0.4	0	0	Non-local
M10	1	NA	0	0	5	0	5	0.5	1	20.0	2	0.4	0	0	Non-local
C25	0	NA	0	3	2	0	5	0.5	2	40.0	1	0.2	0	0	Non-local
R3	0	NA	0	0	4	0	4	0.4	0	0	1	0.3	0	0	Non-local

CH2	0	NA	0	3	0	0	3	0.3	1	33.3	3	1.0	0	0	Non-local
M6	1	NA	0	0	3	0	3	0.3	0	0	0	0	0	0	Non-local
B5	0	NA	0	0	2	0	2	0.2	0	0	1	0.5	0	0	Non-local
C21	0	NA	0	2	0	0	2	0.2	0	0	2	1.0	0	0	Non-local
C22	0	NA	0	1	1	0	2	0.2	1	50.0	1	0.5	0	0	Non-local
C23	2	N (low sample)	0	0	2	0	2	0.2	0	0	0	0	0	0	Non-local
CH1	0	NA	0	2	0	0	2	0.2	0	0	1	0.5	0	0	Non-local
R2	0	NA	0	0	2	0	2	0.2	0	0	0	0	0	0	Non-local
S3	0	N (low sample)	0	2	0	0	2	0.2	0	0	2	1.0	0	0	Non-local
C24	0	M (low sample)	0	1	0	0	1	0.1	0	0	0	0	0	0	Non-local
C26	0	NA	0	1	0	0	1	0.1	0	0	0	0	0	0	Non-local
CH3	0	NA	0	0	1	0	1	0.1	0	0	0	0	0	0	Non-local
M7	0	NA	0	0	1	0	1	0.1	0	0	1	1.0	0	0	Non-local
M8	0	NA	0	0	1	0	1	0.1	0	0	0	0	0	0	Non-local
O1	0	NA	0	0	1	0	1	0.1	0	0	0	0	0	0	Non-local
Q1	0	M (low sample)	0	1	0	0	1	0.1	0	0	1	1.0	0	0	Non-local
Q2	0	NA	0	1	0	0	1	0.1	1	100.0	1	1.0	0	0	Non-local
R4	0	NA	0	0	1	0	1	0.1	0	0	1	1.0	0	0	Non-local

Hypotheses that allow expectations to be developed for how human behavior will be manifested through attributes in the archaeological record can be tested by evaluating the distributions of raw materials at the sites, and lithic attributes which represent activity patterns in comparison to the raw material types. Evaluation of raw material distribution to indicate procurement strategies may first be examined at the level of local and non-local materials.

This evaluation is possible having estimated local and non-local materials of the flakes in the assemblages that could not be securely assigned to a specific source, then recategorizing the assigned Landmark Gap Quarry and Long Tangle Lake artifacts to the local group. XMH-35 and Whitmore Ridge Component 2 were the only assemblages that had nonlocal materials and XHM-35 had the highest percentage of nonlocal material (Figure 5.16). Likewise, XMH-35 has the most raw material diversity and evenness, which will be outlined in detail in subsequent sections. The Landmark Gap Quarry material is makes up a similar percent of the site components for Whitmore Ridge Component 2, Landmark Gap Trail Site, and XMH-35, but is a much higher percentage at Whitmore Ridge Component 1 (Figure 5.17). Long Tangle Lake Quarry material is present in the highest percentages at Landmark Gap Trail Site and XMH-35, and lesser but similar percent at Whitmore Ridge Component 1 and 2 (Figure 5.17).

The amount of local and non-local materials in assemblages is related to procurement strategies. Often non-local materials require longer transport distances and is associated with an increase in richness and evenness among materials at a site. Also, non-local raw materials are often conserved and used for different tool production strategies (such as formal tools rather than expedient tools) than local materials. In the Northern Archaic components, the Landmark Gap Trail Site does not contain any non-local materials, whereas XMH-35 and Whitmore Ridge C2 both contain non-local materials. XMH-35's sample contains 13.7% non-local material and Whitmore Ridge C2's sample contains only 4.8% non-local material (Figure 5.16). This fit the patterns previously described about these sites where non-local materials should be present in late reduction stages, whereas local materials likely will tend to have material in all reduction stages, including the early stages. Therefore, the activities at Landmark Gap Trail site tend towards early reduction stages and XMH-35 tends toward late stage reduction. Whitmore Ridge C2 show patterns of late stage reduction, though also some early stage reduction can be recognized from the patterning of local and nonlocal materials.

All three sites have components associated with the Northern Archaic, but Whitmore Ridge Site also has an older component associated with the Early Holocene Denali Complex. Comparing lithic attributes and raw material distribution between time periods can shed light on changes in procurement strategies through time. When comparing the two components, the first pattern that stands out is the increased use of nonlocal material through time, such that nonlocal material was only used during the Northern Archaic (Figure 5.16, Figure 5.17).

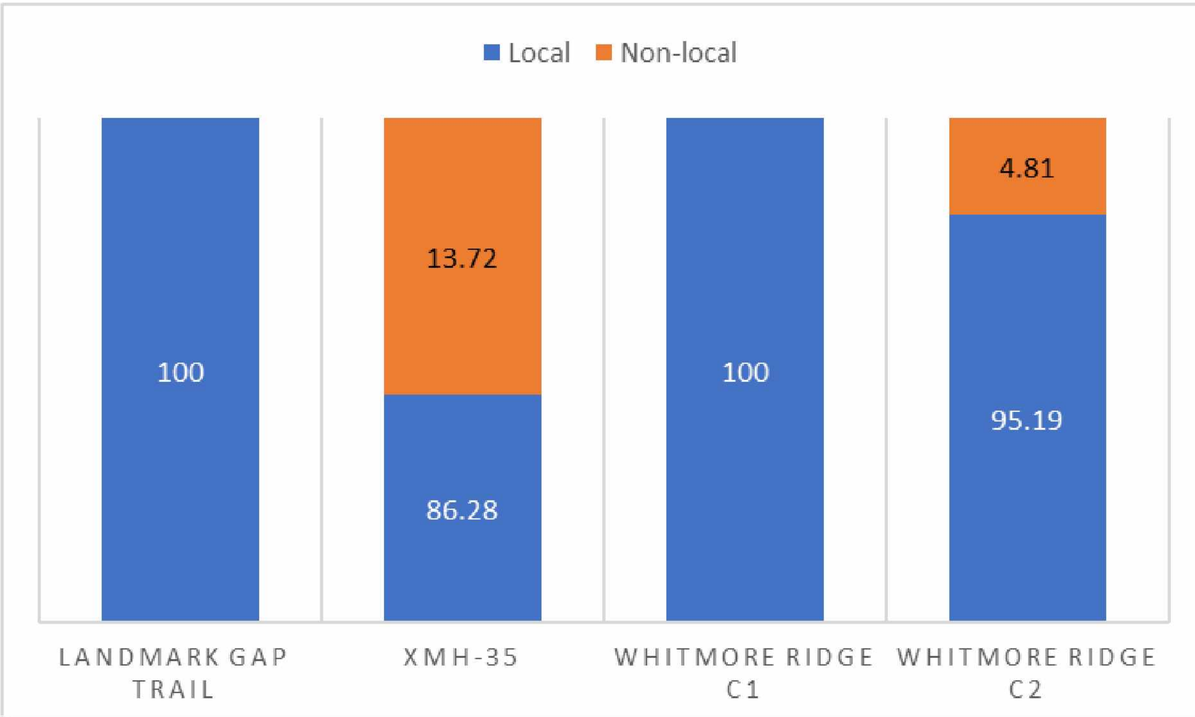

Figure 5. 16 Proportions of local and non-local material in each site component

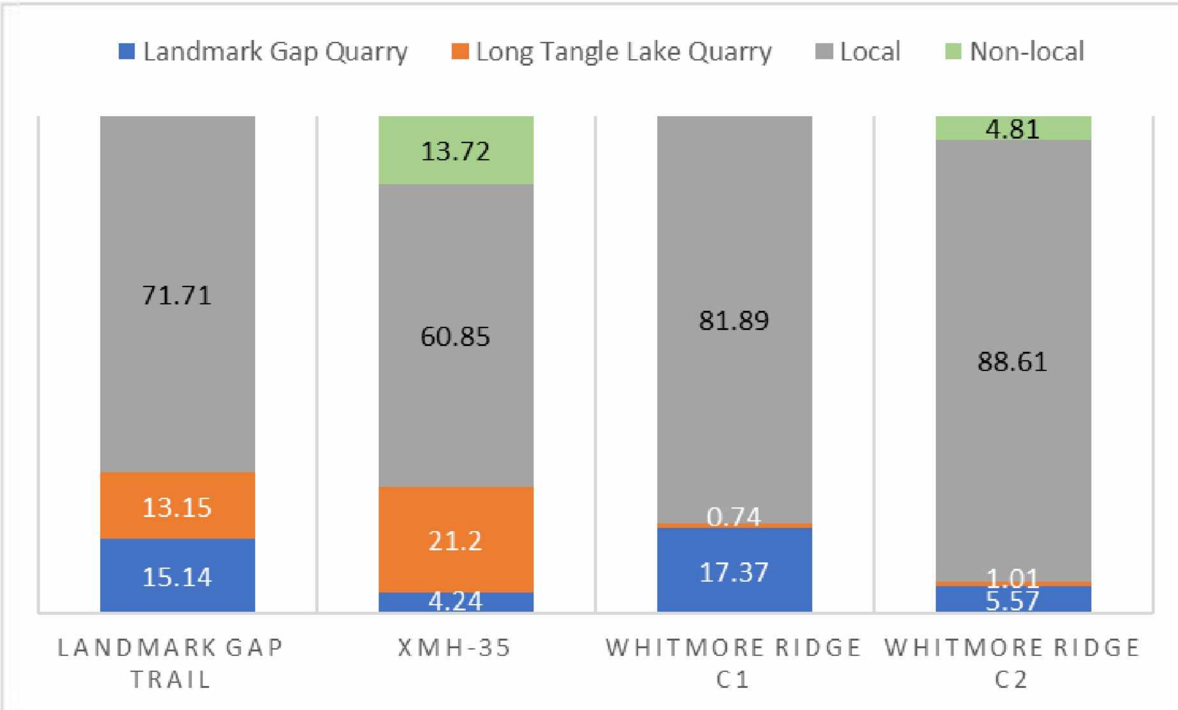

Figure 5.17 Proportions of quarry materials compared to local and non-local in each site component.

5.9 Quarry Attractiveness and Material Distribution Models

Distance between a toolstone source and an archaeological assemblage has proven to be a factor that consistently patterns the archaeological record with regard to transport of raw material from quarry sources. However, many archaeologists have recognized that there are multiple factors relating to toolstone sources that determine the occurrence of particular materials in the archaeological record. Factors such as the extent of the source, exposed bedrock, the quality, size of nodules, difficulty of extraction and terrain are considered extrinsic cost factors that are hypothesized to condition the extent to which the material can be used (Adams and MacDonald 2015; Elston 2013; Soto et al. 2017; Wilson 2007b). The goal of applying an attractiveness model to calculate the extrinsic cost value of toolstone sources is to estimate the expected occurrence of the source material within archaeological sites. Comparing the expected occurrence amount to the actual occurrence amount evaluates if people were extracting the maximum amount of material available based on the model. On one hand, an attractiveness model can define constraints for obtaining material only by what can physically be extracted. In this case, the model predicts how much material can be quarried and therefore how much should occur in lithic assemblages, removing any assumptions about human path choice such as a response to terrain and distance to sites (Soto et al. 2017). The benefit of this approach is that the hypothesis is only based on known constraints about the material. When terrain difficulty and other costs are incorporated into a model it must be assumed that humans choose to act rationally in order to minimize costs of procuring toolstone.

Four models will be explored for the quarries in this project and the related distribution within the four site components. The Northern Archaic residence, XMH-35, yielded the highest proportion of Long Tangle Lake Quarry material compared to the other components, which is much higher than the proportion of Landmark Gap Quarry material at the site (Figure 5.18). The Northern Archaic tool production site, Landmark Gap Trail, also has a high proportion of the Long Tangle Lake Quarry material which is only about 1.9% less than the Landmark Gap Quarry material at the site (Figure 5.19). The Denali and Northern Archaic hunting camp, Whitmore Ridge C1 and C2, have similarly low proportions of the Long Tangle Lake Quarry material and high proportions Landmark Gap Quarry material in comparison (Figure 5.20, 5.21). Questions arise about why and how different proportions of the two quarry materials exist in the site components. The following models test expectations for how procurement strategies and raw material selection are represented by the distributions of quarry lithic materials in sites conditioned by site location, the cost of obtaining material, quarry attractiveness, and material availability. Therefore, multiple independent tests can predict how the quarry materials entered the site components.

The first model looks at the quantitative differences in the quarries as a factor of the materials' distributions, such that distance, terrain, and quality are held equal. It is adapted from Soto et al. (2017) which hypothesizes all else being equal that the ratio of observed occurrence of bedrock quarry material from Landmark Gap Quarry and Long Tangle Lake Quarry can be a proxy for the expected ratio of the Landmark Gap Quarry Material and Long Tangle Lake Quarry material in the archaeological sites (Table 5.2.7). The ratio of the Long Tangle Lake and Landmark Gap Quarry material based on calculations of the material available at each quarry is called the Quarry Abundance Ration or QAR. Following the expectations outlined by Soto et al. (2017), if the ratio of the two materials in site assemblages is similar to the ratio of bedrock material available (QAR), then a procurement strategy is generalist such that material occurrence in assemblages is largely dictated by encountering resources. On the other hand, if the ratio of the materials in the assemblages is different from the QAR, then it may indicate selective procurement of materials. When the four site components are considered together as cases of a chi-square goodness-to-fit test, the QAR is the expected value and the ratios of Long Tangle Lake to Landmark Gap Quarry material in each component are the observed values. Therefore, the null hypothesis states that there is no significant difference between the observed proportions of quarry materials in each component and the expected value based on the QAR. The null hypothesis can also be restated as the different site assemblages have no impact on the selection of quarry materials from the landscape. Therefore, if the null hypotheses are accepted ($\chi^2 \leq 7.81$) then with 95% confidence there is no significant difference between the proportions of the material available on the landscape and in the site assemblages, and the different sites may not impact the selection of material. In this case, it is assumed that generalist procurement of the materials was taking place at the sites. Alternatively, if the null hypothesis is rejected ($\chi^2 \geq 7.81$), then with 95% confidence there is a significant difference between the QAR and the ratio of the materials in the sites, and the sites may impact the selection of material. In this case, it is assumed that certain materials were preferentially treated at the sites in a selectionist procurement strategy.

The second model explores attractiveness of each quarry including the terrain difficulty for traveling between the site assemblages and the sources, material quality, and material abundance measures. It explores interaction of multiple quantifiable factors that could determine selection and distribution of the quarry materials. The model is adapted from Wilson (December 2007), and includes factors: (Quality x extent of source x 100/difficulty of terrain x cost of extraction) x (size/scarcity) (Table 5.2.8; Table 5.2.9; 5.2.10; 5.2.11).

The third model holds qualitative aspects of the quarries equal and examines their location in terms of cost to travel across the landscape in relation to the sites as a conditioning factor of the data (Table 5.2.8; Table 5.2.9; Table 5.9.13)

Finally the fourth model holds qualitative aspects of the quarries equal and examines their location in terms of Euclidian distance in relation to the sites as a conditioning factor of the data (Table 5.2.13).

Models two through four provide “attractiveness” values for each material at each site. If the proportion of the two materials in the site assemblages is the same as the proportion based off of the attractiveness values for each material those factors likely conditioned the procurement of the materials. Evaluation of the lithic attributes of the debitage provide a secondary avenue for understanding procurement strategies associated with these two quarries and other local toolstone sources.

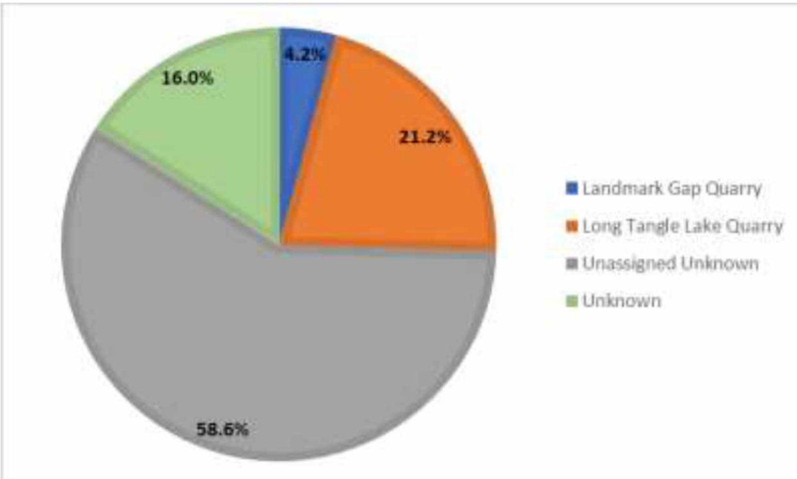

Figure 5.18 Percent of assigned quarry artifacts in the XMH-35 assemblage.

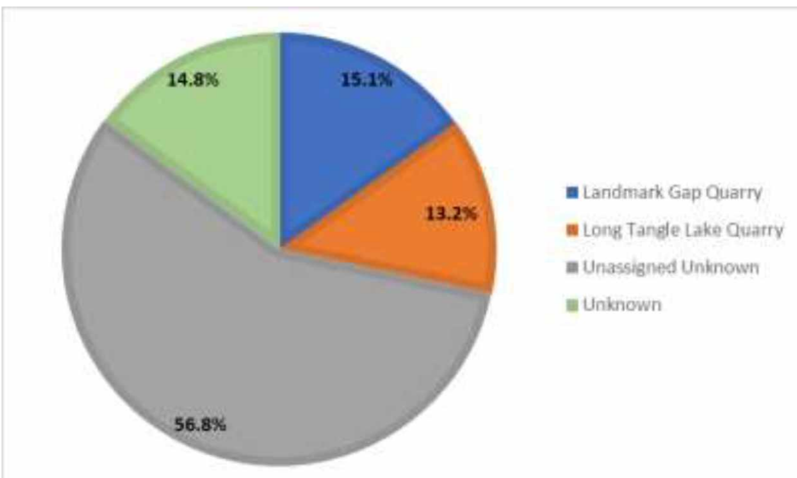

Figure 5.19 Percent of assigned quarry artifacts in the Landmark Gap Trail site assemblage.

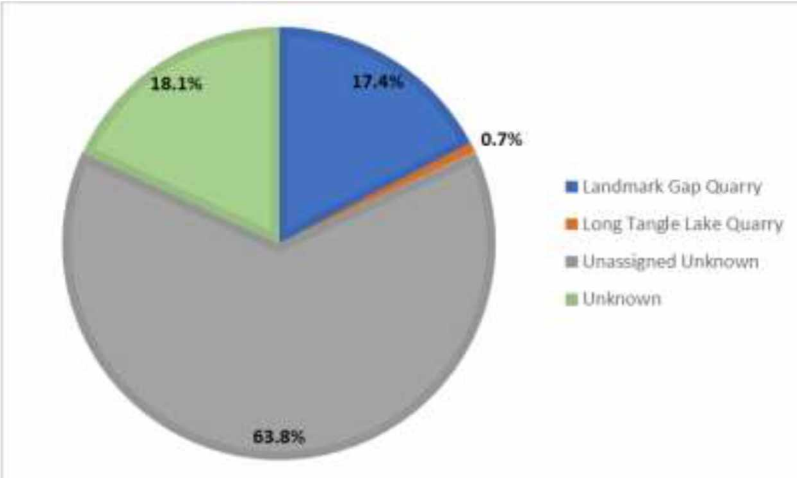

Figure 5.20 Percent of assigned quarry artifacts in Whitmore Ridge Component 1.

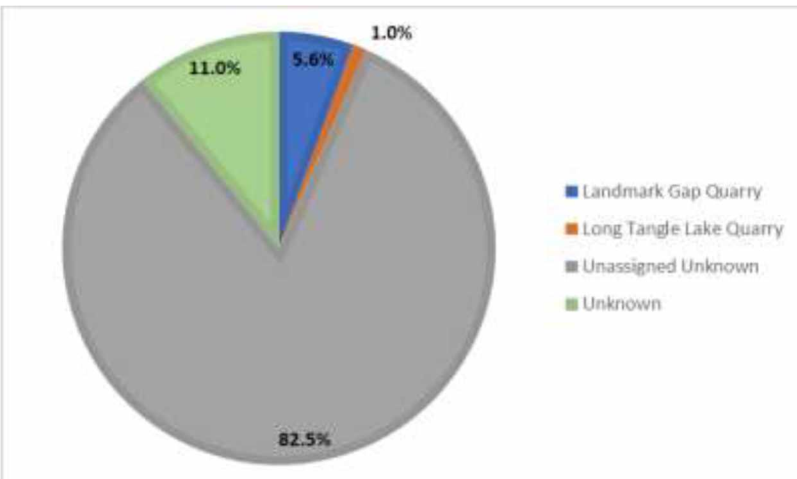

Figure 5.21 Percent of assigned quarry artifacts in Whitmore Ridge Component 2.

Quarry Abundance Ratio

The QAR of value based on these variables collected from each quarry was 2.59. QAR = $\frac{189}{73}$ (Table 5.18). The ratio of Long Tangle Lake Quarry material to Landmark Gap Quarry materials at the sites is based off of abundance of those materials in the site assemblages calculated from the count of artifacts chemically assigned to these quarries from the subsamples of artifacts that could be chemically analyzed (Table 5.18). This assumes that the ratio would be proportional to the rest of the site assemblage if they all could be chemically analyzed. None of the ratios of Long Tangle Lake Quarry to Landmark Gap Quarry material are similar to the QAR, suggesting one of the quarry materials was preferer or selectively procured in each site component. When the four sites are considered as cases, χ^2

=8.14 is greater than the critical value 7.81 (degrees of freedom 3, $P<0.05$), allowing the null hypothesis to be rejected with 95% confidence. Therefore, there is a significant difference between the proportion of quarry materials in each site and the QAR, which suggests differences in site assemblages may have impacted the selection of material. Therefore, it is possible to assume that one quarry material was preferred over the other and selectively procured in each of the site components. XMH-35 is the only site that clearly shows preference for the Long Tangle Lake Quarry material. Both the Denali and Northern Archaic components at Whitmore Ridge show similarly low ratios of the quarry materials, in favor of the Landmark Gap Quarry material. Though the Landmark Gap Trail site has the closest proportion of materials to the QAR, the higher proportion of Landmark Gap Quarry material to Long Tangle Lake Quarry material suggests some preference for the Landmark Gap Quarry.

Table 5.18 Quarry Abundance Ratios and site Long Tangle Lake to Landmark Gap material ratios.

SITE/COMPONENT	RATIO $\frac{\textbf{Long Tange Lake Quarry}}{\textbf{Landmark Gap Quarry}}$
QAR	2.59
XMH-35	5.00
Landmark Gap Trail Site	0.87
Whitmore Ridge C1	0.04
Whitmore Ridge C2	0.18
χ^2 =8.14, there is a significant difference between the QAR and material proportions in the sites, $p<0.05$	

Attractiveness/Gravity Model

The values given below fulfill the variables of the attractiveness equation outlined in Chapter 4.

Material Quality: Long Tangle Lake has a quality score of 42, and Landmark Gap Quarry has a quality score of 21.

Extent of Source: Long Tangle Lake has an extent of source score of 36, and Landmark Gap has an extent of source score of 35.

Size and Scarcity Ratio: Landmark Gap Quarry has a size-scarcity ratio value of 2.78, and Long Tangle Lake has a size-scarcity ratio value of 12.

Difficulty of Terrain: Roundtrip cost values for traveling from each site to each quarry and back were calculated by adding the values of each quarry and site location on cost surfaces (Table 5.19; Table 5.20). The cost surfaces that were added were associated with traveling from the Landmark Gap Quarry (Figure 5.22) and from Long Tangle Lake Quarry (Figure 5.23) to each site, and from XMH-35 (Figure 5.24), Whitmore Ridge (Figure 5.25), and Landmark Gap Trail Site (Figure 5.26) to the two quarries.

Cost of Extraction: Landmark Gap Quarry received a cost of extraction score of 40, and Long Tangle Lake Quarry received a cost of extraction score of 34.

The results of the attractiveness equations show that for every site, even though the cost of travel to and from the Long Tangle Lake Quarry may be more difficult and farther distance, the Long Tangle Lake quarry is more attractive based on all the cost-benefit attributes (Table 5.21, Table 5.22).

Table 5.19 Cost surface calculations from sites to and from the Landmark Gap Quarry.

LANDMARK GAP QUARRY					
Site	To source		Away from source	Roundtrip total value	
	water disadvantage	water advantage		water disadvantage	water advantage
Landmark Gap Trail Site	6,189	NA	6,189	12,378	
Whitmore Ridge	12,200	NA	12,200	24,400	
XMH-35	25,826	13,538	25,826	51,653	39,364

Table 5.20 Cost surface calculations from sites to and from the Long Tangle Lake Quarry.

LONG TANGLE LAKE QUARRY					
Site	To source		Away from source	Roundtrip total value	
	water disadvantage	water advantage		water disadvantage	water advantage
Landmark Gap Trail Site	27, 658	20,064	27,658	55,316	47,722
Whitmore Ridge	24,655	14,584	24,655	49,309	39,238
XMH-35	39,807	15,833	39,807	79,614	55,640

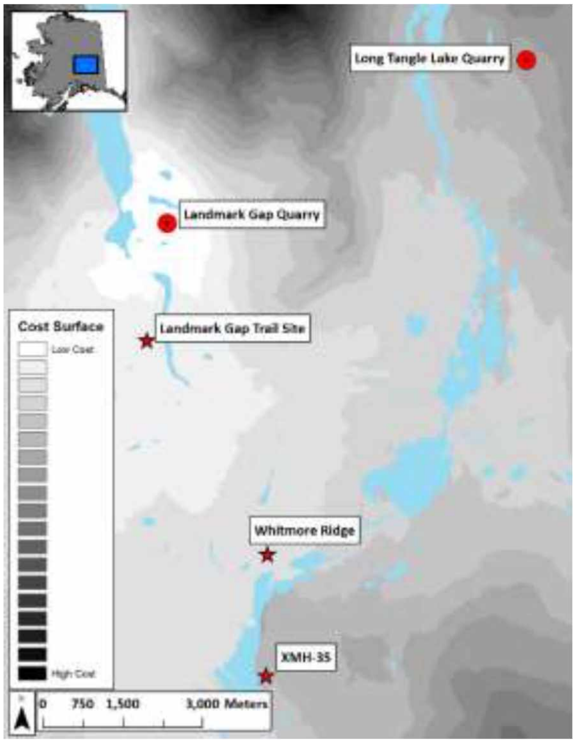

Figure 5.22 Cost surface associated with movement away from the Landmark Gap Quarry.

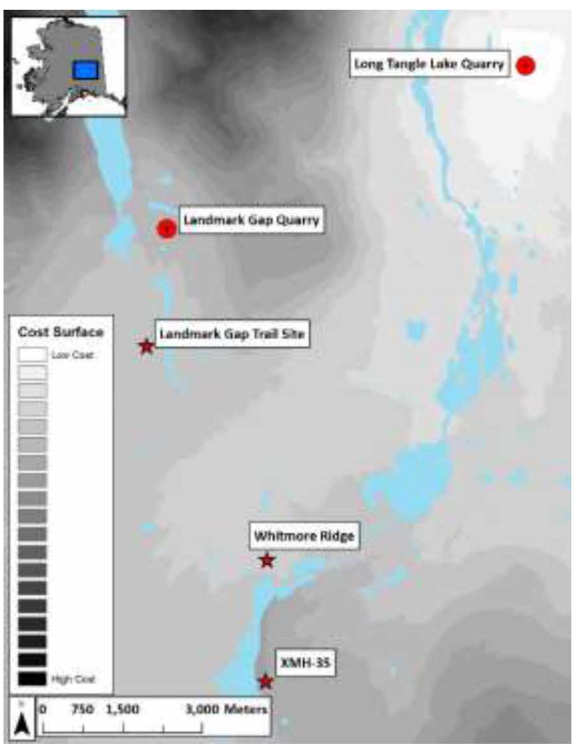

Figure 5.23 Cost surface associated with movement away from the Long Tangle Lake Quarry.

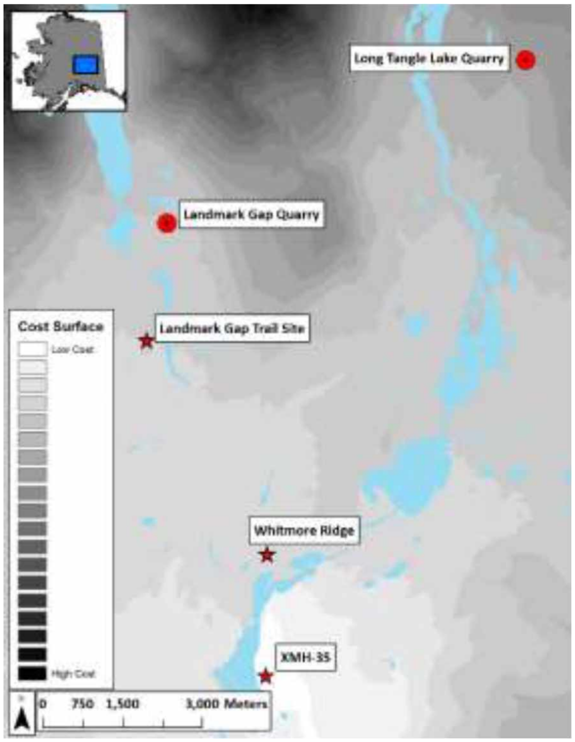

Figure 5.24 Cost surface associated with movement away from the XMH-35.

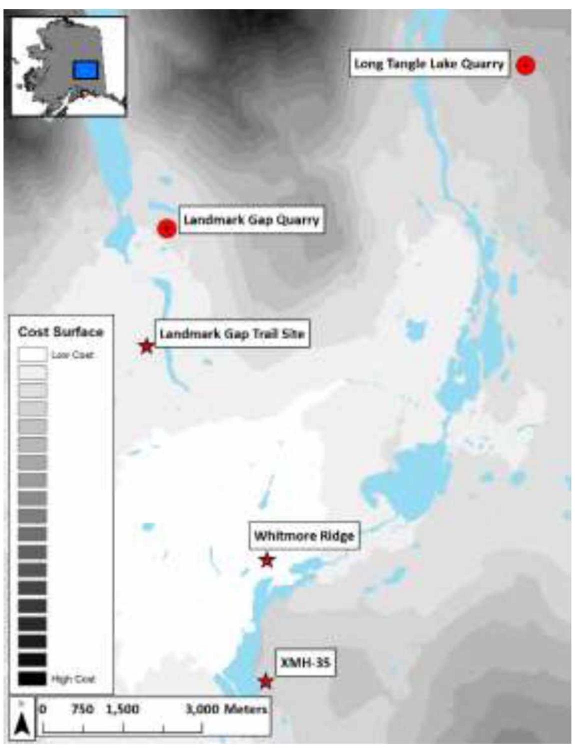

Figure 5.25 Cost surface associated with movement away from Whitmore Ridge.

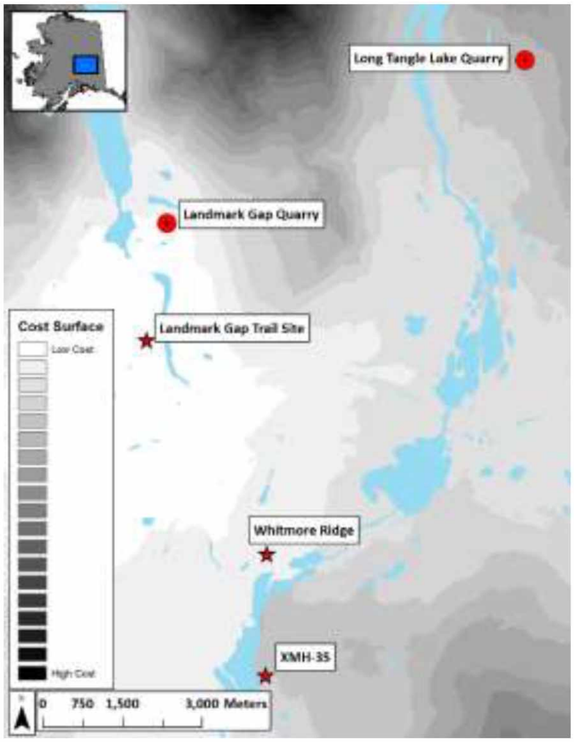

Figure 5.26 Cost surface associated with movement away from the Landmark Gap Trail Site.

Table 5.21 Attractiveness values that were calculated for each site relative to each quarry. The value is calculated in terms of obtaining the most optimal material and transporting the material to each site using the cost surface.

Quarry	Site	Attractiveness value (smaller the number the higher the cost) (the higher the number the more attractive)
Landmark Gap Quarry		
	Landmark Gap Trail Site	0.41
	Whitmore Ridge	0.21
	XMH-35	0.13
Long Tangle Lake Quarry		
	Landmark Gap Trail Site	1.12
	Whitmore Ridge	1.36
	XMH-35	0.96

Table 5.22 Attractiveness values that were calculated for each site relative to each quarry. The value is calculated in terms of obtaining the most optimal material and transporting the material to each site using Euclidean distance rather than the cost surface.

Quarry	Site	Attractiveness value (smaller the number the higher the cost)
Landmark Gap Quarry		
	Landmark Gap Trail Site	2,288.6
	Whitmore Ridge	788.46
	XMH-35	589.34
Long Tangle Lake Quarry		
	Landmark Gap Trail Site	6,050.3
	Whitmore Ridge	5,110.6
	XMH-35	4,264.7

Generally, the results of the cost distance and Euclidean distance-decay models provide basis for the expectations that all else being equal there should be more meta-tuff from Landmark Gap Quarry than meta-chert from Long Tangle Lake in all the site assemblage samples (Table 5.23). The only site assemblages that clearly meet those expectations for the cost distance/distance-decay model are Whitmore Ridge C1 and C2 (Figure 5.20, Figure 5.21). The Landmark Gap Trail site also meets the expectations for the cost distance/distance decay models but yields an almost even proportion of the Long Tangle Lake and Landmark Gap Quarry materials; there is only 1.9% more Landmark Gap Quarry material than Long Tangle Lake Quarry material (Figure 5.19). The proportions of materials at XMH-35 clearly do not meet the expectations for the cost distance/distance-decay models (Figure 5.18). These results stand out and require more examination. The Landmark Gap Trail Site is less than 3km from the Landmark Gap Quarry and archaeologists that have excavated this site over the years have assumed with great certainty that most if not all of the non-igneous cryptocrystalline silicate material at the site was coming from the Landmark Gap Quarry (Table 5.23). Therefore, it makes sense that there would be more Landmark Gap Quarry at this site; however, the high proportion of the Long Tangle Lake Quarry material is surprising, considering the quarry is approximately 9 km away from the, in a different mountain valley, and across a river is surprising (Figure 5.23). Alternatively, the Landmark Gap Quarry was clearly utilized as shown by the high proportion of Landmark Gap Quarry material at Whitmore Ridge which is about 4km farther away from this source than the Landmark Gap Trail site (Figure 5.2.20, Figure 5.21, Table 5.23). The low proportion of Landmark Gap Quarry material at XMH-35, and high proportion of Long Tangle Lake Quarry material at both XMH-35 and the Landmark Gap Trail site begs the question: why were prehistoric people at these sites acquiring the Long Tangle Lake Quarry at such distances and high costs? Therefore, an encompassing model based on attractiveness of each quarry may be useful for answering this question.

Table 5.23 Cost distance and Euclidean distance-decay model values.

Quarry	Site	Cost Surface (units)	Euclidean Distance (km)
Landmark Gap Quarry			
	Landmark Gap Trail Site	12,376.95	2.232
	Whitmore Ridge	24,399.80	6.480
	XMH-35	39,363.75	8.668
Long Tangle Lake Quarry			
	Landmark Gap Trail Site	47,721.75	8.820
	Whitmore Ridge	39,238.17	10.442
	XMH-35	55,639.50	12.513

Based on the results of the attractiveness model, it is expected that there would be more Long Tangle Lake Quarry material in all site assemblages (Table 5.24). XMH-35 clearly meets these expectations, while Whitmore Ridge C1 (Denali Complex) and C2 (Northern Archaic) both do not meet these expectations (Table 5.24). The Landmark Gap Trail site also does not meet the expectations for the attractiveness model based on a higher presence of the Landmark Gap Quarry material at this site when considered alone; however, it does offer a reason for the almost even proportion of Long Tangle Lake Quarry material at this site.

These results lead to the next set of hypotheses. It is hypothesized that raw material use varied spatially, rather than temporally. Secondly, it is hypothesized that a similar procurement strategy was employed to obtain local materials at Landmark Gap Trail Site and XMH-35, while a different procurement strategy was likely the result of a Whitmore Ridge C1 and C2 components. The failure of the sites to meet expectations can be addressed by evaluating the debitage attributes in terms of raw material group to determine more specific procurement strategies at each component.

The amount of local and non-local materials including more specific designations of Landmark Gap Quarry and Long Tangle Lake Quarry is a general way of showing richness and evenness in the assemblages, which is often a function of source location. For the Northern Archaic components, XMH-35 has the highest proportion of non-local material and Long Tangle Lake material (Figure 5.17), and based on the QAR the Long Tangle Lake Quarry material was preferred (Table 5.24). In a direct procurement sense non-local materials have the highest procurement cost. At XMH-35, the Long Tangle Lake Quarry has a greater cost for acquisition (ratio of Landmark Gap Cost to Long Tangle Lake Cost is 0.71) but has a better overall attractiveness value than Landmark Gap Quarry (Table 5.24). There is less Landmark Gap Quarry material at XMH-35 even though it is less costly to obtain (Figure 5.19; Table 5.24); however, the higher proportion of Long Tangle Lake Quarry material could be due to overall high attractiveness of the Long Tangle Lake Quarry. The presence of a small proportion of Landmark Gap material could mean it was directly procured for certain activities, or it was part of an embedded procurement system where the cost to obtain more attractive materials such as Long Tangle Lake Quarry material and non-local material was lower than in a direct procurement system. Therefore, the cost of obtaining the materials would be more even and the attractiveness of the materials from the quarries would influence the amount obtained.

It is unexpected that the Landmark Gap Trail site has an almost even proportion of Long Tangle Lake Quarry material. Though the ratio of each material compared to the QAR shows preference for the closer Landmark Gap material, the high presence of the Long Tangle Lake material is surprising. The cost of obtaining Long Tangle Lake Quarry material is significantly higher than Landmark Gap Quarry material (Table 5.24). The ratio of cost to obtain Landmark Gap Quarry material over Long Tangle Lake Quarry material is 0.26, which is a significantly lower ratio than at XMH-35. Even more surprising, the lithic debitage show patterns indicating that the site associated with early reduction stages. The overall attractiveness of the Long Tangle Lake Quarry material is higher than the Landmark Gap Quarry material, the more costly but more attractive Long Tangle Lake material could have been used for different activities than the local materials. It is hypothesized that the local materials and Landmark Gap Trail Quarry material will make up the majority of the debitage that represents early reduction stages, whereas late stage reduction will be associated with the Long Tangle Lake material.

Whitmore Ridge C2 differs from the other Northern Archaic sites because the Landmark Gap Material is significantly more prevalent than Long Tangle Lake Quarry material (Figure 5.21) and based on the QAR there is clearly preference for the Landmark Gap Quarry material (Table 5.24). This makes sense in terms of cost, but not attractiveness, as Long Tangle Lake is more costly to obtain but also more attractive overall than Landmark Gap Quarry. This suggests a more direct procurement strategy of the materials, while the entrance of non-local materials could be due to the likelihood of multiple occupations occurring at the site. The Denali component at Whitmore Ridge (C1) is similar to the Northern Archaic component (C2) with regards to raw material distribution, based on the QAR the Landmark Gap Quarry material is clearly preferred. One difference is that the Denali complex component at Whitmore Ridge did not yield any non-local raw materials (Figure 5.16, Figure 5.17). Therefore the richness and evenness of materials in this site was lower than all the Northern Archaic components. After local material, the second highest proportion of material was Landmark Gap Quarry material, and there is a small amount of Long Tangle Lake Quarry material (Figure 5.17). Therefore, it is possible that the procurement strategies that were the result of the material accumulating at this site did not change through time though technological strategy did. Therefore it is possible that overall site type did not change significantly.

Table 5.24 Distributional model comparison. The table shows the distance, cost-distance, and attractiveness values in comparison to the results of the QAR material abundance model**.**

Quarry	Site	Cost Surface (units)	Euclidean Distance (km)	Attractiveness value (units) ↑units = ↑attractiveness	RATIO $\frac{\text{Long Tange Lake Quarry}}{\text{Landmark Gap Quarry}}$ ↑value = more LTL than LMG	
Landmark Gap Quarry					QAR	2.59
	Landmark Gap Trail Site	12,376.95	2.232	0.41	XMH-35	5.00
	Whitmore Ridge	24,399.80	6.480	0.21	Landmark Gap Quarry	0.87
	XMH-35	39,363.75	8.668	0.13	Whitmore Ridge C1	0.04
Long Tangle Lake Quarry					Whitmore Ridge C2	0.18
	Landmark Gap Trail Site	47,721.75	8.820	1.12		
	Whitmore Ridge	39,238.17	10.442	1.36		
	XMH-35	55,639.50	12.513	0.96		

5.10 Diversity Indices

The results of the diversity measures show that XMH-35 is the most diverse component with regards to material types (Table 5.25). Landmark Gap Trail Site has the second highest diversity index values, which surprising because it is the closest site to a raw material source (Table 5.25). Whitmore Ridge Component 1 and 2 are close in terms of their raw material diversity being the lowest of the three sites. Component 1 of Whitmore Ridge is more diverse than Component 2 (Table 5.25). XMH-35 has the most material richness and highest evenness (Table 5.25). Landmark Gap Trail Site and Whitmore Ridge have equally the lowest raw material richness but Landmark Gap Trail Site has much high raw material evenness than the Whitmore Ridge components (Table 5.25). Whitmore Ridge Component 2 has the lowest evenness. These results can easily be compared to the cost of acquiring each material for each component and the attractiveness of each quarry material for each component. The patterns identified by the diversity measures independently reiterate the results of the distribution models. The diversity measures indicate a direct procurement strategy was practiced by both the Denali and Northern Archaic populations at Whitmore Ridge, which reiterates a direct procurement strategy based on these components adhering to the cost/distance-decay models rather than the attractiveness model and preference for the Landmark Gap Quarry material based on the QAR. Diversity measures indicate an embedded procurement strategy was practiced by Northern Archaic populations at XMH-35, which reiterates embedded procurement strategy suggested for the Long Tangle Lake Quarry material based on selection of this material despite high cost and distance, but adherence to the attractiveness model. Diversity measures also indicate that embedded procurement was practiced at the Landmark Gap Trail site, which provides clarity for why there is an almost even proportion of the Long Tangle Lake and Landmark Gap Quarry material, despite the high cost of the Long Tangle Lake material.

Another line of evidence to understand the procurement of materials is by evaluating diversity measures in terms of the quarry abundance ratios, representing the proportions of Long Tangle Lake Quarry and Landmark Gap Quarry material in the assemblages. If a quarry material was acquired by means of an embedded procurement strategy, it is expected it would be associated with greater overall assemblage diversity. Likewise, if a quarry material is associated with low assemblage diversity, than it is expected this material was direct procured. The results of comparing the two diversity measures and evenness values with the quarry abundance ratios at each site show (1) that the two diversity measures are comparable (Figure 5.27, Figure 5.28), and (2) that sample diversity and evenness increases as the proportion of Long Tangle Lake material increases, and decreases as the Landmark Gap material increases (Figure 5.2.27, Figure 5.28 Figure 5.29). Therefore, these results reiterate that large proportions of the Long Tangle Lake Quarry material likely was incorporated into the Landmark Gap Trail site and XMH-35 via embedded procurement.

Table 5.25 Diversity measures for Landmark Gap Quarry material (LMG) and Long Tangle Lake Quarry material (LL) in site assemblages.

Component	Date	C14 error (+/-)	Complex	LMG Cost	LL Cost	LMG Attractiveness	LL Attractiveness	QAR (LL/LMG = 2.589)	Richness (S)	Evenness (H'/ln(s))	Hmax (LN(S))	Shannon-Wiener H'	Simpson's D (0-1)
XMH-35	4450	140	Northern Archaic	39364	55640	0.13	0.96	5.00	4	1.00	1.39	1.04	0.57
Whitmore Ridge C1	9953	60	Denali	24400	39238	0.21	1.36	0.04	3	0.48	1.10	0.50	0.30
Whitmore Ridge C2	5143	199	Northern Archaic	24400	39238	0.21	1.36	0.18	4	0.44	1.39	0.46	0.21
Landmark Gap Trail	4330	135	Northern Archaic	12377	47722	0.41	1.12	0.87	3	0.76	1.10	0.76	0.45

Figure 5.27 Ratio of Long Tangle Lake Quarry material to Landmark Gap Quarry material in each component sample, compared to Simpson's material diversity index in each component.

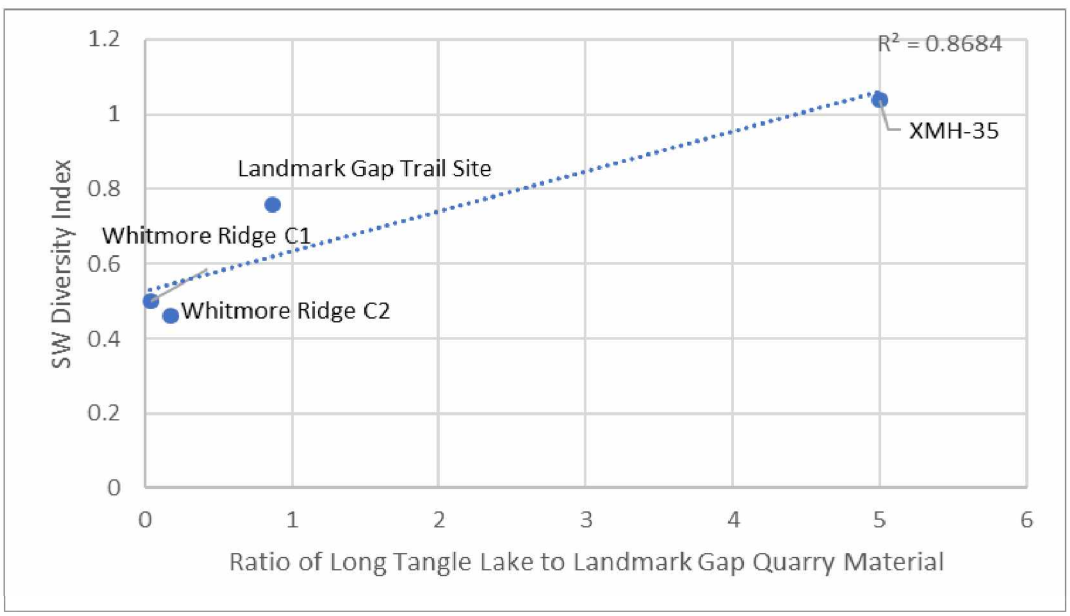

Figure 5.28 Ratio of Long Tangle Lake Quarry material to Landmark Gap Quarry material in each component sample, compared to SW material diversity index in each component.

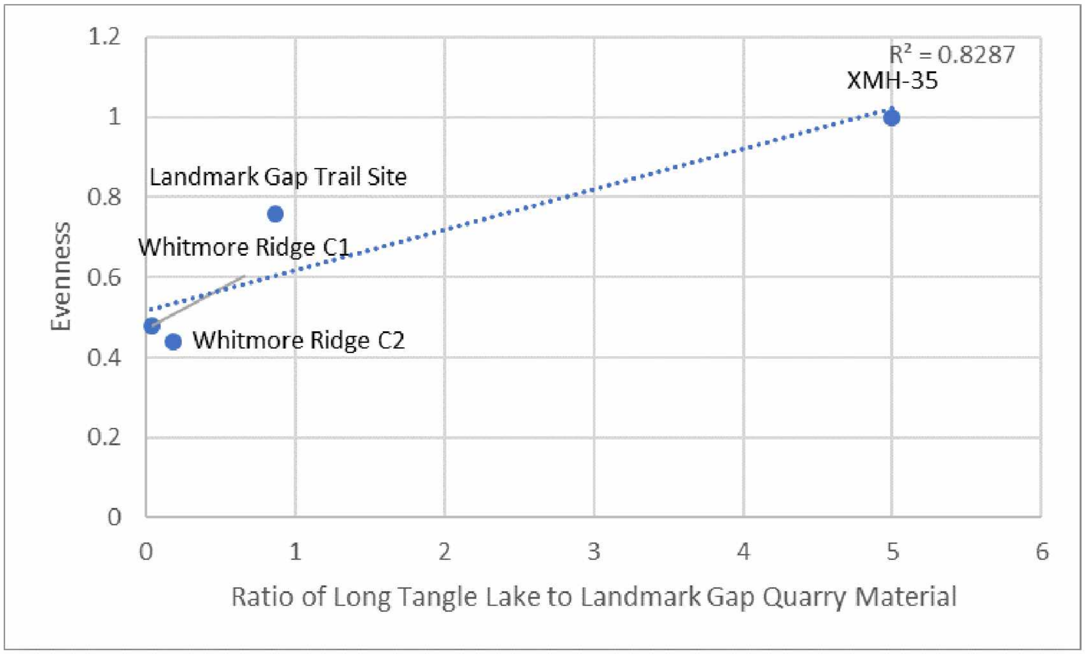

Figure 5.29 Ratio of Long Tangle Lake Quarry material to Landmark Gap Quarry material in each component sample, compared to material evenness in each component.

5.11 Intrasite Raw Material and Technological Patterns

XMH-35

The Landmark Gap Quarry material and the Long Tangle Lake Quarry material are both considered local, however Long Tangle Lake Quarry is more costly to obtain but also more attractive overall for transport to each of the sites in this study. Simple flakes dominate the XMH-35 sample, the second most frequent flake type in the sample is the bifacial thinning flake (Table 5.26). The pattern of raw material use may indicate preferential use of material for certain technological types. The highest proportion of simple flakes is in the raw material category of Landmark Gap Quarry, followed by unidentified local materials (Table 5.26). In contrast these same two raw material groups have the lowest proportions of bifacial thinning flakes (Table 5.26). The Landmark Gap Quarry material has the lowest proportion of bifacial thinning flakes (Table 5.26). Landmark Gap Quarry and the local material group were the only two material groups with bipolar flakes (Table 5.26). Bipolar flakes are thought to indicate raw material conservation which does not meet expectations for the material, therefore bipolar flaking technique could be associated with the quality and nodule size of the material. Long Tangle Lake

Quarry has the highest proportion of bifacial thinning flakes compared to the other materials, followed by non-local materials (Table 5.26). It is possible that Long Tangle Lake material and non-local materials were preferred for bifacial production. Further, bifaces may factor into an embedded procurement strategy, where the knowledge of the landscape will allow for more attractive but more costly sources to be exploited in the subsistence round. Since bifaces were likely used in the subsistence round stages of bifacial re-sharpening could have taken place after their use in the subsistence round, and new material for biface production could have been procured at the same time (Rasic and Andrefsky 2001). This hypothesis may also be supported by the proportion of decortication flakes of the Long Tangle Lake Quarry material and the non-local material. Long Tangle Lake Quarry has the highest proportion of decortication flakes compared to the other materials at 8.2%, which is followed by non-local materials at 5.5% (Table 5.26). Unidentified local material also has decortication flakes at 2.9%, which is expected for local material in the early reduction stage sequence (Table 5.26).

The non-local materials, the Long Tangle Lake Quarry material, and the local material all had similar distributions of platforms (Table 5.26). The most similar distributions of platform types were in the local and nonlocal material categories, which had the highest proportions of complex platforms followed by abraded platforms (Table 5.26). The Long Tangle Lake Quarry had the highest proportion of complex platforms and second highest proportion of abraded platforms (Table 5.26). However, the Long Tangle Lake Quarry had a slightly higher proportion of cortical platforms and lower proportion of abraded platforms than the non-local and local materials. The Landmark Gap Quarry material distribution of platform types stands out. The proportion of simple and complex platforms is even and therefore there is a lower proportion of complex platforms than the other materials within the site (Table 5.26). There is a lower proportion of abraded platforms and a much higher proportion of crush platforms than the other materials (Table 5.26). Finally there are no cortical platforms made of material from the Landmark Gap Quarry (Table 5.26). This indicates that the Long Tangle Lake Quarry, local, and non-local materials were reduced in all stages at the site, and were used for a variety of technology including the production and reduction of bifaces. However, the Landmark Gap Quarry material was treated differently, it was not reduced in early stages at the site, but was likely used for more expedient technology than bifacial technology because of the lower proportion of complex and abraded platforms. The crushed platforms may suggest hard hammer blows for reducing larger nodules of material that was possibly more difficult to fracture because of its quality.

The cortex and dorsal scar count comparisons in terms of material were limited to the assigned material from the Landmark Gap Quarry and the Long Tangle Lake Quarry. Dorsal scar count and cortex amount was used to estimate the local and non-local materials as these lithic attributes are often strongly associated with distance decay models of reduction. The most apparent difference in the way that Landmark Gap Quarry material and Long Tangle Lake Quarry material is being treated at XMH-35 is that the Long Tangle Lake Quarry material was being transported to the site as nodules with more cortex, as seen by 3.6% of the flakes from this quarry had more than 50% cortex (Table 5.26). On the other hand, there were no flakes from Landmark Gap Quarry with 50% or more cortex (Table 5.26). This may be a result of the nodule and quarrying qualities of the bedrock at each quarry. The Long Tangle Lake nodules are much easier to break off or remove in controlable sizes or pick up in cubes, while the Landmark Gap Quarry material takes more effort to quarry and eventually a large piece will break off of the bedrock, which presumably would require further immediate reduction for transport. It is possible that Long Tangle Lake Quarry mateiral is simply more easily picked up in the midst of other subsistence activities, associated with its increased attactiveness and suitability for embedded procurement. However, Landmark Gap Quarry material may take more time and energy at the source to reduce for transport and may not have been an effective source to visit while performing other subsistence activities, and the presence of this material in lithic assemblages may be the result of direct procurement.

The dorsal scar count can indicate reduction stage and type of technology the material was used for. The quarry materials have similarly high distributions of flakes with greater than four dorsal scars, which suggests use for bifacial reduction, and generally late stage reduction (Table 5.26). Though all stages of reduction seem to be represented by both materials, there is a clear difference in proportion of flakes with two dorsal scars (Table 5.26). Flakes with two dorsal scars make up 27.3% of the assemblage from Landmark Gap Quarry, while only 10.7% of flakes have two dorsal scars from Long Tangle Lake Quarry (Table 5.26). Because the earliest stages of reduction do not seem to be the main focus, it is possible that this pattern is an indication that Landmark Gap Quarry material was used more for expedient technology, rather than curated tools.

High proportions of broken and complete flakes for all the materials suggests that tool production was a primary activity in this site despite the material type (Table 5.26). The general local material has the highest proportion of flake fragments that could be associated with expedient technology and early stage reduction (34.0%), (Table 5.26).

The metric measures of the materials at XMH-35 have consistent general patterns, such that Landmark Gap Quarry material occupies smaller size classes and has less variation, except for a small proportion isolated in the largest size classes (Figure 5.30, Figure 5.31, Figure 5.32). This indicates that the reduction strategies for each material occurring at the site were relatively similar, except for Landmark Gap Quarry that may have been reduced elsewhere, entering the site in smaller pieces, or the nodules obtained from the quarry were smaller than the others.

The weight distribution is similar to the metric size measures distributions in that the Long Tangle Lake Quarry and the Landmark Gap Quarry material have more representation in larger size classes and less in the smallest size class (Figure 5.33). The pattern seen here, resulting in the difference between the known quarries and the local and non-local material likely is a result of sampling for chemical analysis. Size limitations resulted in the smallest flakes not being analyzed on the Niton pXRF and therefore less assigned to the quarries. The smallest flakes tend to be less representative of qualitative lithic attributes, however the metric measures likely show the slight bias in the material distribution. Therefore, it is best to compare the Landmark Gap Quarry material weights to the Long Tangle Lake Quarry weights. Proportions of the smallest three size classes are similar for both materials; however Long Tangle Lake Quarry material has small percentages of material in more of the larger size classes than Landmark Gap Quarry material (Figure 5.33). Alternatively, Landmark Gap Quarry has a slightly higher proportion of material in the 8th and 10th largest weight classes (Figure 5.33).

The proximal end attributes of flakes made on these materials will indicate how the different materials were being flaked and prepared. Lipping is not present on the majority of flakes made of all the materials (Table 5.26). The Landmark Gap Quarry material and the Long Tangle Lake Quarry material has almost the same proportion of flakes with lipping at 40% and 31.3%, respectively (Table 5.26). The general local material has a proportion of flakes with lipping in between the other materials at 35% (Table 5.26).

All the materials have a higher proportion of diffuse bulbs of percussion indicating soft hammer percussion on all materials. However, Long Tangle Lake Quarry material has a noticeably higher proportion of flakes with salient bulbs of percussion with a percentage of 21.7% than Landmark Gap, 6.7% (Table 5.26). This higher proportion of salient bulbs suggests that hard hammer percussion was used more on the Long Tangle Lake Quarry material than Landmark Gap Quarry material. It is possible that this is another indication that some of the Long Tangle Lake Quarry material could have been entering the site in more complete nodule form and reduced on site, rather than Landmark Gap Quarry material that may have been initially reduced at the source.

Again, the proportion of erailure scars is very similar for each material, especially the Long Tangle Lake Quarry material (35.3%) and the Landmark Gap Quarry material (33.3%) (Table 5.26). However, the majority of all the flakes in the sample, regardless of material type, do not have an erailure scar (Table 5.26). Thus is it likely that soft hammer percussion was generally used for all materials. There is a possibility that hard hammer percussion was used in slightly more cases for Long Tangle Lake Quarry material. However, for the most part the materials were percussed in the same ways.

Table 5.26 Lithic attributes recorded on lithic debitage from for each material at XMH-35. The percent of total debitage sample of each material with particular attributes was calculated.

Attribute		% Landmark Gap Quarry	% Local	% Long Tangle Lake Quarry	% Non-local
cortex amount Cramer's V-square 0.01	none	81.8	85.8	4.8	85.5
	0-50%	18.2	12.5	3.6	9.1
	>50%	0	1.7	10.7	5.5
dorsal scar count Cramer's V-square 0.02	0	4.6	8.3	10.7	3.6
	1	4.6	3.3	27.4	5.5
	2	27.3	17.1	42.9	10.9
	3	9.1	22.9	20.6	16.4
	4	18.2	16.3	13.2	18.2
	>4	36.4	32.1	31.3	45.5
platform type Cramer's V-square 0.01	abraded	20.0	27.4	22.4	26.8
	complex	33.3	38.9	35.8	39.0
	cortical	0	3.8	7.5	2.44

	crushed	26.7	8.9	13.4	12.2
	simple	20.0	21.02	20.9	19.5
Sullivan and Rozen typology Cramer's V-square 0.01	broken	58.8	35.7	47.1	49.1
	complete	29.4	26.6	31.8	21.8
	fragment	11.8	34.0	20.0	21.8
	shatter	0	0.8	0	1.8
	split	0	2.9	1.2	5.5
flake type Cramer's V-square 0.01	bifacial thinning	11.8	12.7	17.7	18.2
	bipolar	5.9	1.6	0	0
	core part	0	0.8	0	1.8
	decortication	0	2.9	8.2	5.5
	modified flake	0	0.4	0	0
	shatter	0	81.6	0	1.8
	simple	82.4	60.5	74.1	72.7
erailure scar Cramer's V-square 0.00	present	33.3	39.5	35.3	34.2
	absent	66.7	80.4	64.7	65.9
lipping Cramer's V-square 0.01	present	40.0	35.0	31.3	26.8
	absent	60.0	65.0	68.7	73.2
bulb of percussion Cramer's V-square 0.02	salient	6.7	12.1	21.7	17.1
	diffuse	93.3	87.9	78.3	82.9

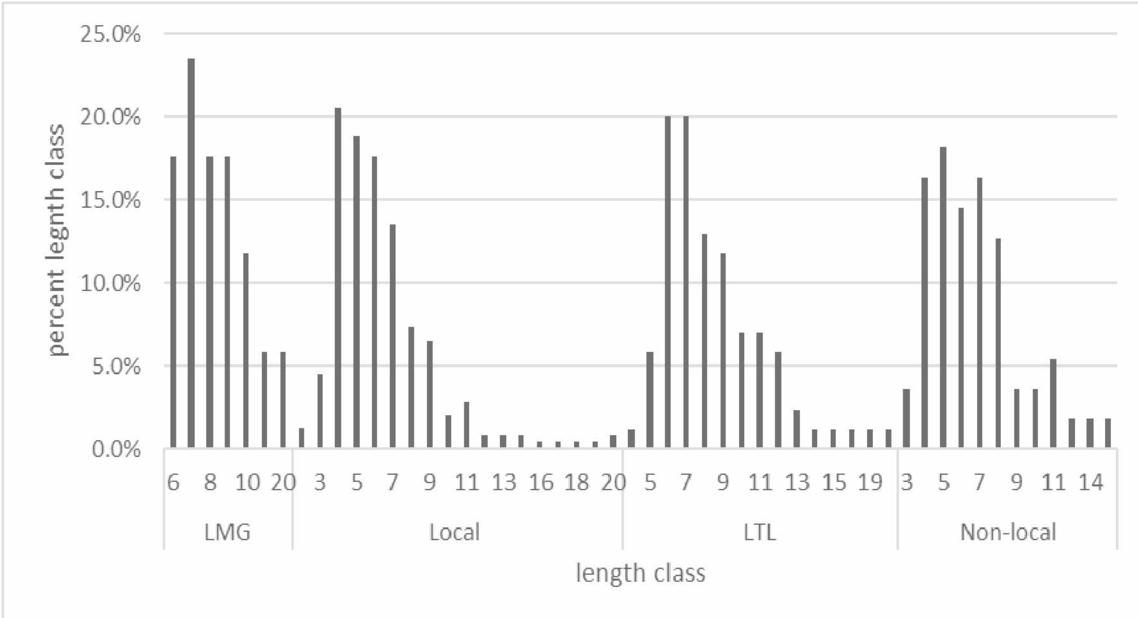

Figure 5.30 Distribution proportions of artifacts assigned to length classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at XMH-35.
Cramer's V-square = 0.07

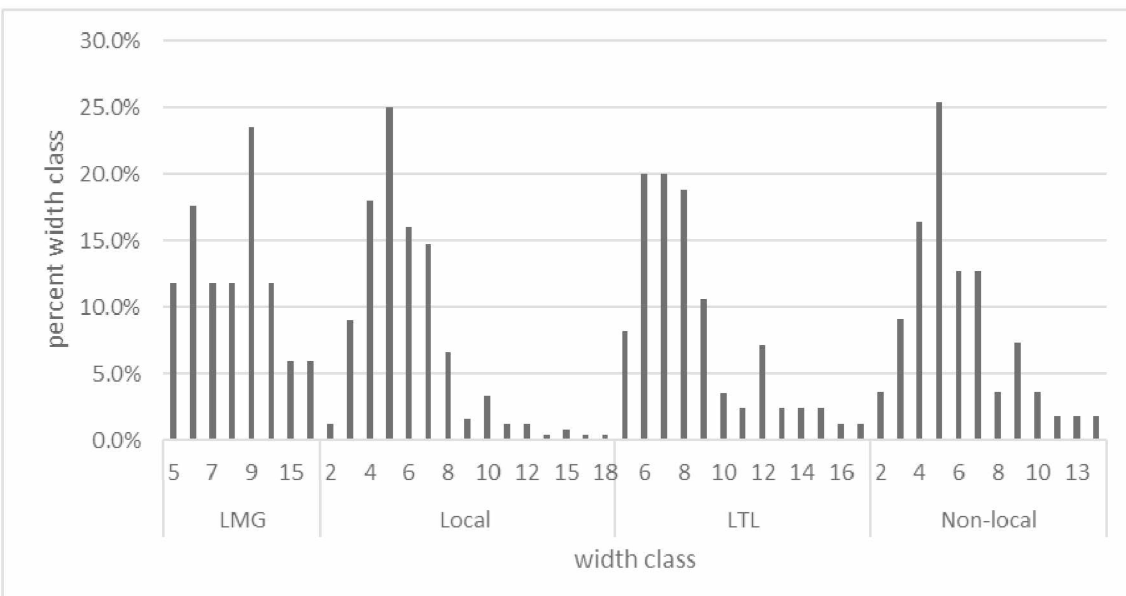

Figure 5.31 Distribution proportions of artifacts assigned to width classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at XMH-35.
Cramer's V-square = 0.10

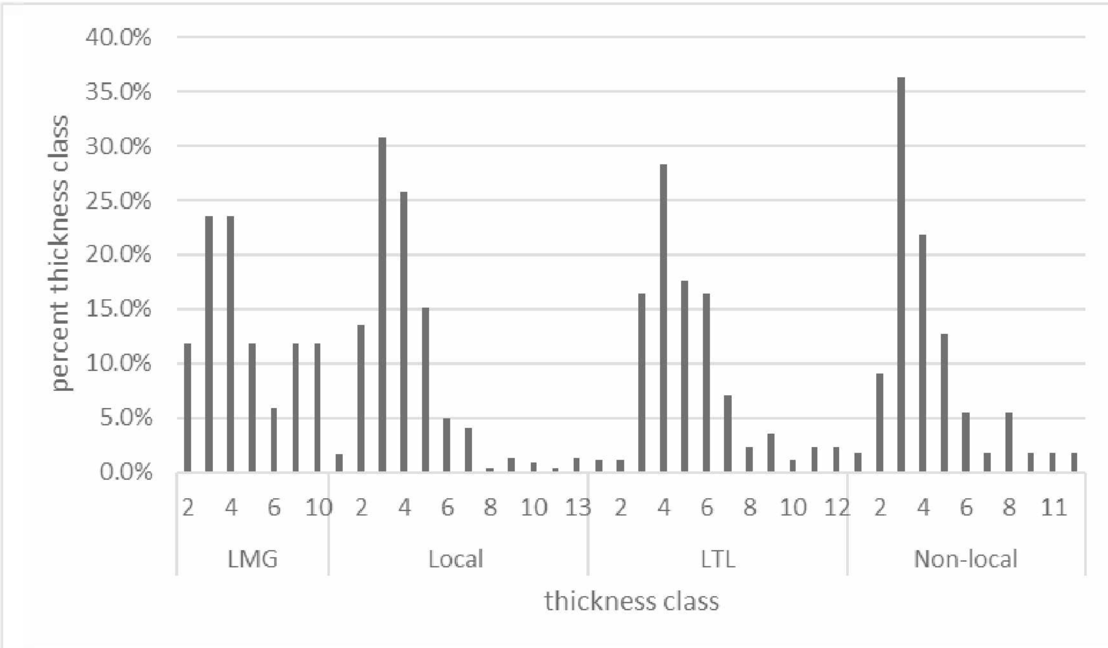

Figure 5.32 Distribution proportions of artifacts assigned to thickness classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at XMH-35.
Cramer's V-square = 0.06

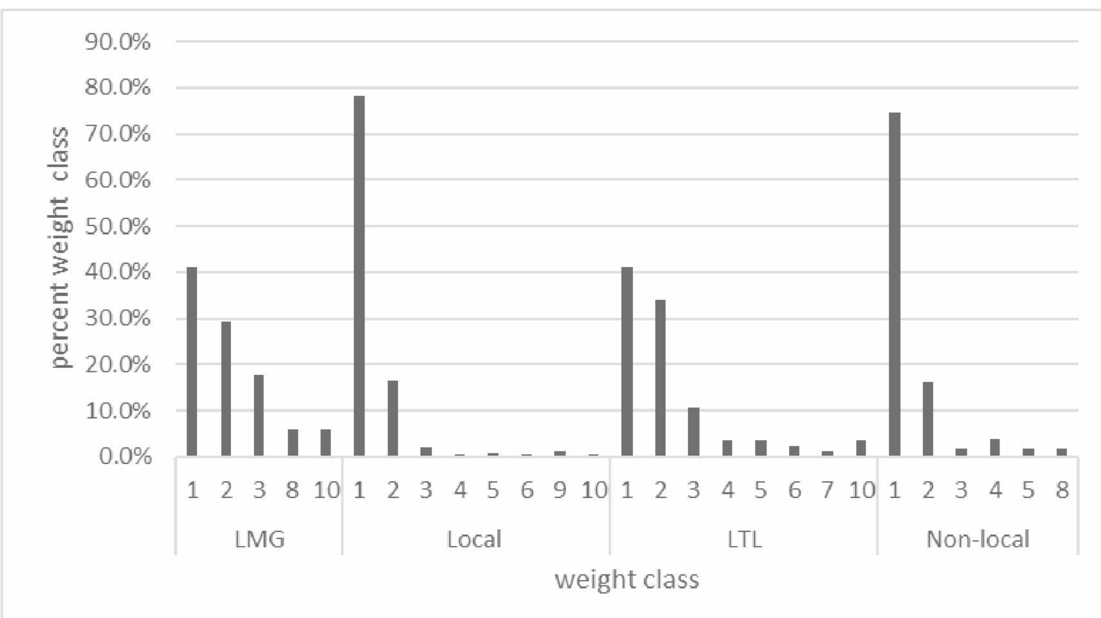

Figure 5. 33 Distribution proportions of artifacts assigned to width classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at XMH-35.
Cramer's V-square = 0.07

Landmark Gap Trail Site

The most apparent general pattern when looking at the material distribution in Feature 1 of the Landmark Gap Trail site, is that there are no estimated non-local materials. Of the local materials it is apparent that they are being used for different technological types. 6.6% of flakes made on Landmark Gap Quarry material are bifacial thinning flakes, in contrast to only 1.9% bifacial thinning flakes made on Long Tangle Lake material (Table 5.27). The estimated local material also has bifacial thinning flakes at 1.0% of the sample (Table 5.27). The estimated local material has the most technological variation, as would be expected based on it having the largest sample size and potentially representing multiple material sources. Landmark Gap Quarry material also has the highest proportion of simple flakes (85.3%) but lowest proportion of decortication flakes (6.6%) than the other materials (Table 5.27). Alternatively, Long Tangle Lake Quarry has the highest proportion of decortication flakes (35.9%) (Table 5.27). This supports the pattern for the materials that was highlighted based on the distribution of flake attributes between materials at XMH-35, that Long Tangle Lake Quarry material was transported to the site as unreduced nodules, whereas Landmark Gap Quarry material was likely reduced at the procurement site.

Landmark Gap Quarry material has an equal proportion of flakes with abraded and simple platforms, both individually accounting for 22.2% of the sample (Table 5.27), but also the highest proportion of complex platforms (44.4%). There are no cortical platforms from the Landmark Gap Quarry, the rest of the platforms on the flakes are crushed (Table 5.27). Alternatively, Long Tangle Lake Quarry has 13.5% of flakes that have cortical platforms (Table 5.27). Proportions of simple platforms are slightly higher than proportions of abraded, cortical, and crushed platforms. Long Tangle Lake Quarry material has the second highest proportion of complex platforms at 43.2% (Table 5.27). The estimated local material is fairly comparable to Long Tangle Lake Quarry with regards to platform type, except it has the highest proportion of simple platforms (31.3%) (Table 5.27). Energy and time input into preparing platforms for tool production was slightly different for the two quarry materials. It seems that both expedient and formal technologies were produced from Landmark Gap Quarry material, while there may have been more of a focus on reducing the Long Tangle Lake Quarry material in all stages at Landmark Gap Trail site and also deliberately producing tools.

The Long Tangle Lake Quarry material has slightly higher proportions of broken and complete flakes than the Landmark Gap material but the proportions are close. The Long Tangle Lake Quarry material also has a slightly lower proportion of flake fragments (30.2%) than Landmark Gap Quarry material (39.3%) (Table 5.27). The local material is slightly different in that it has a proportion of flake fragments (42.6%) that is greater than broken flakes (36.0%) (Table 5.27). It also has the lowest proportion of complete flakes of all the materials (11.5%) (Table 5.27). However, it is reasonable to assume given that broken and complete flakes tend to indicate tool production, that tools were being produced at the site from all the materials and relatively evenly between Landmark Gap Quarry material and Long Tangle Lake Quarry material.

The Landmark Gap Quarry has a much lower proportion of flakes with cortex, totaling 9.8% with cortex, none of which have greater than 50% cortex (Table 5.27). Whereas, the Long Tangle Lake Quarry has 39.6% of flakes with cortex, 3.8% with greater than 50% cortex (Figure 5.2.46). This is again an indicator that the quarrying attributes of the material may have been affecting how these materials were differentially transported to and reduced at the sites, such that Landmark Gap Quarry material was reduced near the quarry, while Long Tangle Lake Quarry material was transported in a form closer to the original cobble.

The dorsal scar counts on flakes in the sample are different for the two quarry materials as well. Flakes of all reduction stages with dorsal scar counts from none through greater than four are present in the sample of Long Tangle Lake Quarry material, though the highest proportion of the material is flakes with more than 4 dorsal scars (47.2%) (Table 5.27). Alternatively, the highest proportion of the Landmark Gap Quarry material (23.0%) were flakes with three dorsal scars (Table 5.27). This is another indicator that both expedient and formal tools were produced at Landmark Gap Trail site from the Landmark Gap Quarry material but the early stages of material reduction took place elsewhere. While, material from the Long Tangle Lake Quarry was more likely used to produce formal tools by reducing the entire nodule at the site.

The metric measures of the flakes of each material are consistent distributions between the length (Figure 5.34), width (Figure 5.35), and thickness classes (Figure 5.36) for all the materials. The Landmark Gap Quarry material tends to be unimodal such that most proportions of material are similar for different size classes. Thirty percent of the Landmark Gap Quarry material falls evenly between length classes eight and nine, and no length classes longer than class 19 are represented (Figure 5.34). Therefore, there is not much variation/diversity in the length classes represented but there is more consistency in the length classes that are represented (Figure 5.34). The local material seems to have a normal but positively skewed distribution in terms of length classes, such that all length classes are represented (Figure 5.34). The width and thickness classes have similar overall distributions as the length classes were described (Figure 5.35, Figure 5.36).

The weight classes have similar distributions to the other metric measures. All materials are positively skewed to the smaller weight classes (Figure 5.37). The local material has the highest proportion of the lowest weight class at 46.4% but also has flakes that fall into almost every weight class (Figure 5.37). The Long Tangle Lake sample falls into more different weight classes than Landmark Gap Quarry material (Figure 5.37). On the other hand, the Landmark Gap Quarry material has less representation in a variety of weight classes, with the highest proportion in the third weight class and no material in the weight classes greater than 15 (Figure 5.37).

The proximal end flake patterns suggest that similar percussion techniques were used on all the material in that the majority of flakes had diffuse bulbs of percussion (Table 5.27) and no lipping (Table 5.27). However, the Landmark Gap Quarry material had the most even distribution between soft hammer percussion indicators and hard hammer percussion indicators (salient bulbs and lipping). The attribute that stands out are erailure scars. The Long Tangle Lake Quarry material and the Landmark Gap Quarry material have the same proportion of erailure scars to no erailure scars at 50% across the board (Table 5.27). This suggests that both hard and soft hammer percussion was used for these materials, where as soft hammer percussion likely was used more for other estimated local materials.

Table 5.27 Lithic attributes recorded on lithic debitage from for each material at the Landmark Gap Trail site. The Percent of total debitage sample of each material with particular attributes was calculated.

Attribute		% Landmark Gap Quarry	% Local	% Long Tangle Lake Quarry	% Non-local
cortex amount Cramer's V-square 0.02	none	90.2	75.8	56.6	0
	0-50%	9.8	22.8	39.6	0
	>50%	0	1.4	3.8	0
dorsal scar count Cramer's V-square 0.03	0	4.9	12.1	7.6	0
	1	1.6	6.6	3.8	0
	2	9.8	21.1	18.9	0
	3	23.0	21.45	13.2	0
	4	18.0	12.8	9.4	0
	>4	42.6	26.0	47.2	0
platform type Cramer's V-square 0.00	abraded	22.2	20.3	13.5	0
	complex	44.4	36.8	43.2	0
	cortical	2.8	6.8	13.5	0
	crushed	8.3	4.9	13.5	0
	simple	22.2	31.3	16.2	0
Sullivan and Rozen typology Cramer's V-square 0.01	broken	44.3	36.0	52.8	0
	complete	13.1	12.1	15.1	0
	fragment	39.3	42.6	30.2	0
	shatter	0	0	0	0
	split	3.3	9.3	1.9	0
flake type Cramer's V-square 0.04	bifacial thinning	6.6	1.0	1.9	0
	bipolar	1.6	0	0	0

	core part	0	0.7	0	0
	decortication	6.6	16.3	35.9	0
	modified flake	0	0	0	0
	shatter	0	82.0	0	0
	simple	85.3	60.5	62.3	0
erailure scar	present	31.6	27.7	51.4	0
Cramer's V-square 0.02	absent	68.4	72.4	48.7	0
lipping	present	43.2	28.2	73.0	0
Cramer's V-square 0.01	absent	56.8	71.8	27.0	0
bulb of percussion	salient	34.2	19.3	20.5	0
Cramer's V-square 0.20	diffuse	65.8	80.7	79.5	0

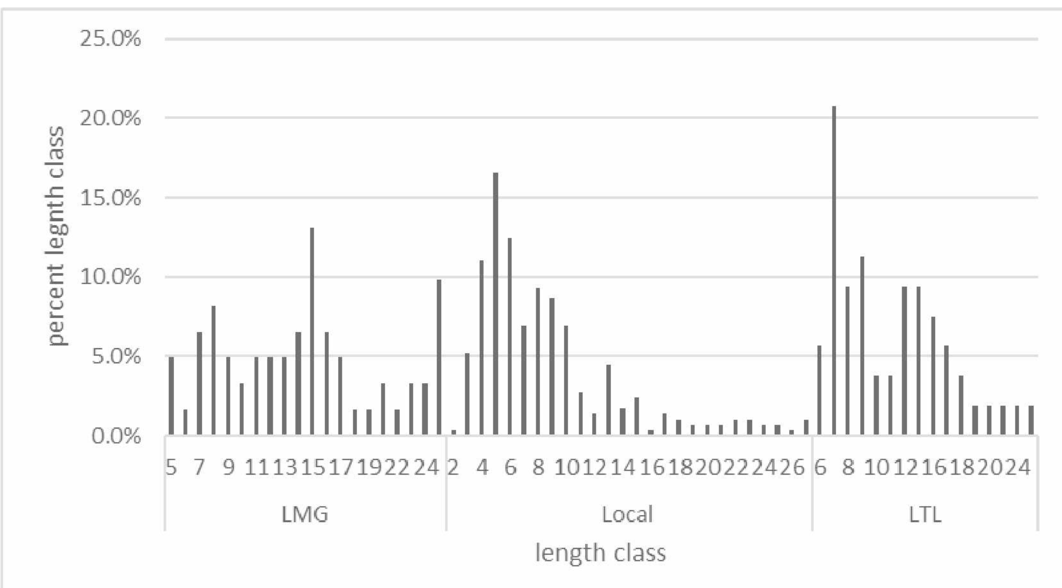

Figure 5.34 Distribution proportions of artifacts assigned to length classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Landmark Gap Trail site. Cramer's V-square = 0.16

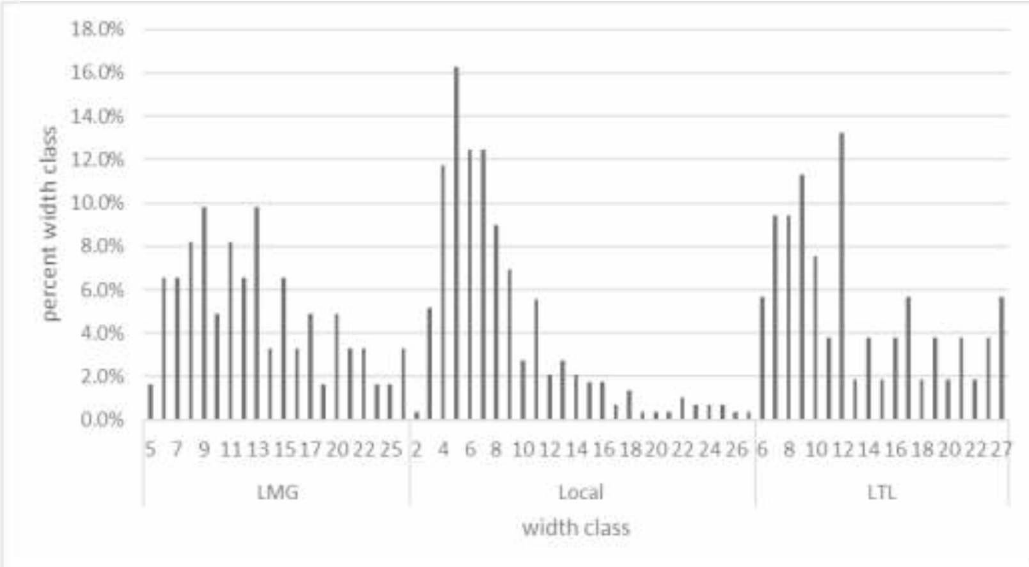

Figure 5.35 Distribution proportions of artifacts assigned to width classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Landmark Gap Trail site. Cramer's V-square = 0.14

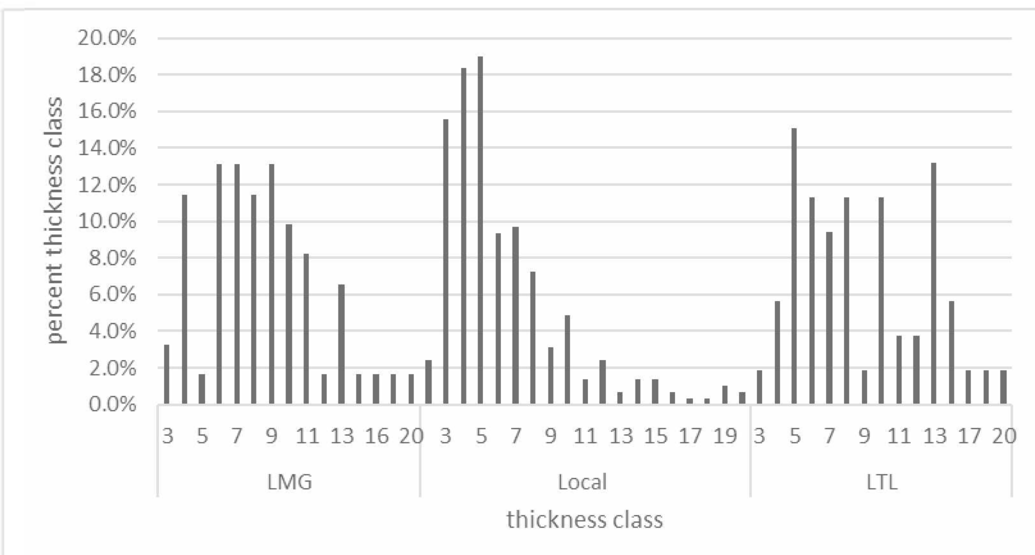

Figure 5.36 Distribution proportions of artifacts assigned to thickness classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Landmark Gap Trail site. Cramer's V-square = 0.12

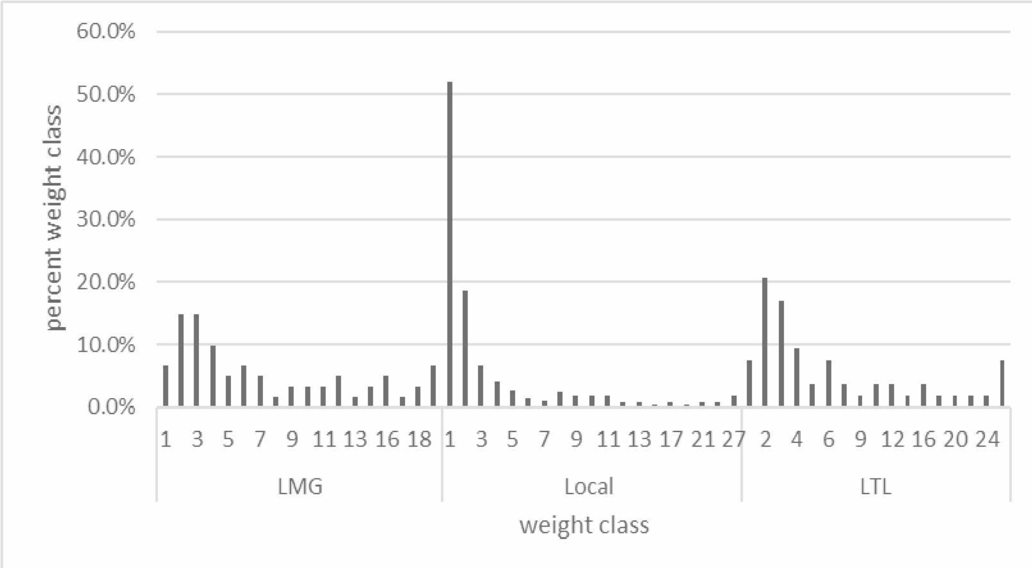

Figure 5.37 Distribution proportions of artifacts assigned to weight classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Landmark Gap Trail site. Cramer's V-square = 0.17

Whitmore Ridge C2

The number of flakes in the assemblage sample for Whitmore Ridge C2 is very small for those assigned to the Long Tangle Lake Quarry (n=3). Of the flakes assigned to Long Tangle Lake Quarry 25.0% are bifacial thinning flakes, 25.0% are simple, and 50.0% are decortication flakes (Table 5.28). This pattern aligns with the patterns from the other sites, that the material was reduced in entirety at the site itself and used to produce formal tools, specifically bifaces. The majority of the assemblage sample is assigned to estimated local materials and are simple flakes (n=302), 86.3% of the local materials (Table 5.28). The estimated non-local materials have the second highest proportion of bifacial thinning flakes (15.8%) (Table 5.28). The Landmark Gap Quarry material represents the second highest proportion of the materials that produced simple flakes (77.3%) and decortication flakes (9.1%) (Table 5.28). It seems as though some of the Landmark Gap Quarry material was reduced from a nodule at the site, but mainly arrived at the site with having already accomplished the early reduction stages, yet the material was being used to produce expedient tools.

Complex platforms are on the majority of flakes that are in this assemblage, followed by flakes with simple platforms for all materials except for the Landmark Gap Quarry which has more abraded platforms (Table 5.28). Surprisingly, there are no abraded platforms on flakes made of Long Tangle Lake Quarry material (Table 5.28). In contrast to the other sites, the Landmark Gap Quarry material has flakes with cortical platforms (8.3%), whereas the Long Tangle Lake Quarry does not (Table 5.28). It is possible that Long Tangle Lake Quarry material was primarily used for bifacial reduction and production of expedient tools, while early stage reduction and various tool production took place with the Landmark Gap Quarry material.

When comparing cortex (Table 5.28) amount and dorsal scar count proportions (Table 5.28) for both the Landmark Gap Quarry material and the Long Tangle Lake Quarry material, it is apparent there is much more variation in the Landmark Gap Quarry material. This may merely be a result of quantity of the material in this sample. However, it also represents the early reduction stages and the later stages are more evenly represented in the Landmark Gap Quarry material at this site.

Another interesting difference in how the materials were being used is apparent from the Sullivan and Rozen typology. There are no flake fragments that are Long Tangle Lake Quarry material (Table 5.28), only broken and complete flakes. This is another strong indicator that at this site, Long Tangle Lake material was primarily used for tool production and biface reduction. In contrast, the Landmark Gap Quarry material has almost equal proportions of broken flakes and fragments, 45.5% and 40.9% respectively (Table 5.28). It also has a low proportion of complete flakes, proportional to the other materials (13.6%) (Table 5.28). This is another sign of early reduction in addition to tool production using the Landmark Gap Quarry material.

The differences in the length classes appears extreme because of the small sample assigned to the Long Tangle Lake Quarry. The Landmark Gap Quarry has flakes that show the most variety in lengths and evenness across the longer length classes (Figure 5.38). Alternatively, there are no flakes that are the Landmark Gap Quarry material that are shorter than the sixth length class out of 24 (Figure 5.38). Long Tangle Lake Quarry's small sample includes only medium and long lengths (Figure 5.38). The other size classes are similar in their distribution to the length classes (Figure 5.39, Figure 5.40). The most apparent difference is in weight class (Figure 5.41).

The measures of the proximal end flakes hard hammer percussion stands out for Long Tangle Lake Quarry due to no lipping present on the flakes (Table 5.28) and erailure scars present (Table 5.28) and 25.0% salient bulbs of percussion (Table 5.28). The rest of the material seems to conform with a pattern of both hard hammer and soft hammer percussion, with more of a reliance on soft hammer percussion.

Table 5.28 Lithic attributes recorded on lithic debitage from for each material at the Northern Archaic component of Whitmore Ridge (C2). The Percent of total debitage sample of each material with particular attributes was calculated.

Attribute		% Landmark Gap Quarry	% Local	% Long Tangle Lake Quarry	% Non-local
cortex amount Cramer's V-square 0.02	none	72.7	89.7	50.0	84.2
	0-50%	18.2	8.3	50.0	10.5
	>50%	9.1	2.0	0	5.3
dorsal scar count Cramer's V-square 0.01	0	9.1	24.0	25.0	31.6
	1	9.1	9.4	0	5.3
	2	18.2	26.0	0	10.5
	3	27.3	22.0	0	10.5
	4	18.2	7.4	0	10.5
	>4	18.2	11.1	75.0	31.6
platform type Cramer's V-square 0.01	abraded	25.0	15.0	25.0	20.0
	complex	33.3	25.6	25.0	50.0
	cortical	8.3	7.2	0	0
	crushed	16.7	20.6	25.0	0
	simple	16.7	31.7	25.0	30.0
Sullivan and Rozen typology	broken	45.5	33.4	50.0	36.8
	complete	13.6	15.4	50.0	15.8

Cramer's V-square 0.00	fragment	40.9	47.7	0	47.4
	shatter	0	0	0	0
	split	0	3.4	0	0
flake type Cramer's V-square 0.04	bifacial thinning	0	2.0	25.0	15.8
	bipolar	0	0.3	0	0
	core part	0	0.6	0	0
	decortication	9.1	4.3	50.0	0
	modified flake	4.6	0.6	0	0
	shatter	9.1	6.0	0	10.5
	simple	77.3	86.3	25.0	73.7
erailure scar Cramer's V-square 0.05	present	23.1	17.1	75.0	60.0
	absent	76.9	82.9	25.0	40.0
lipping Cramer's V-square 0.02	present	38.5	23.0	0	40.0
	absent	61.5	77.0	100	60.0
bulb of percussion Cramer's V-square 0.03	salient	23.1	13.9	25.0	40.0
	diffuse	76.9	86.1	75.0	60.0

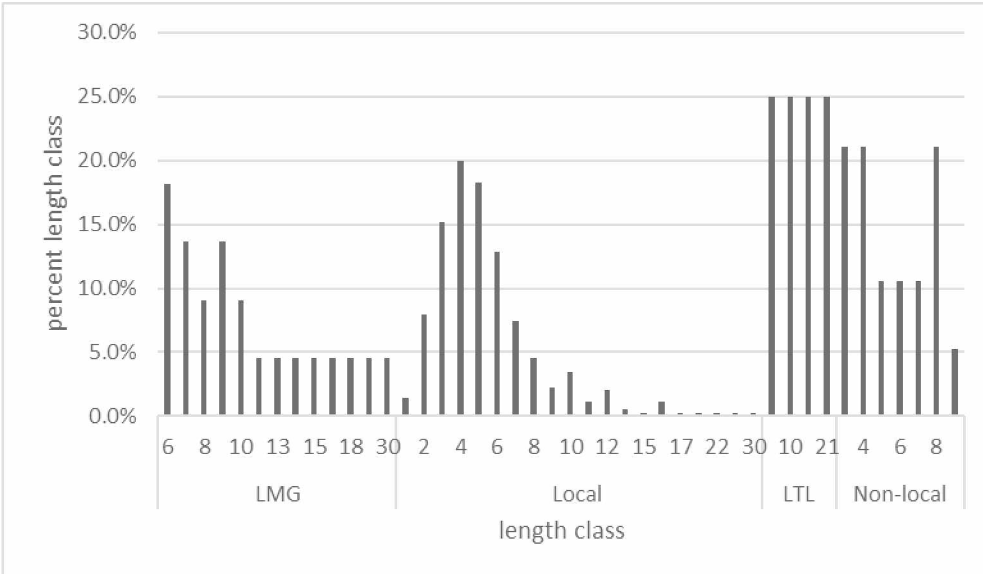

Figure 5.38 Distribution proportions of artifacts assigned to length classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Northern Archaic component of Whitmore Ridge. Cramer's V-square = 0.20

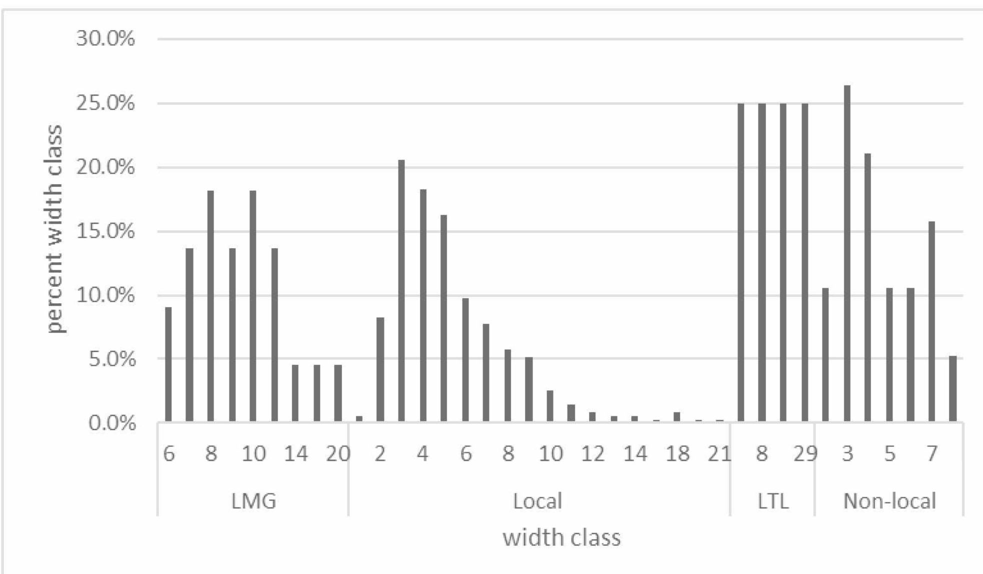

Figure 5.39 Distribution proportions of artifacts assigned to width classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Northern Archaic component of Whitmore Ridge. Cramer's V-square = 0.08

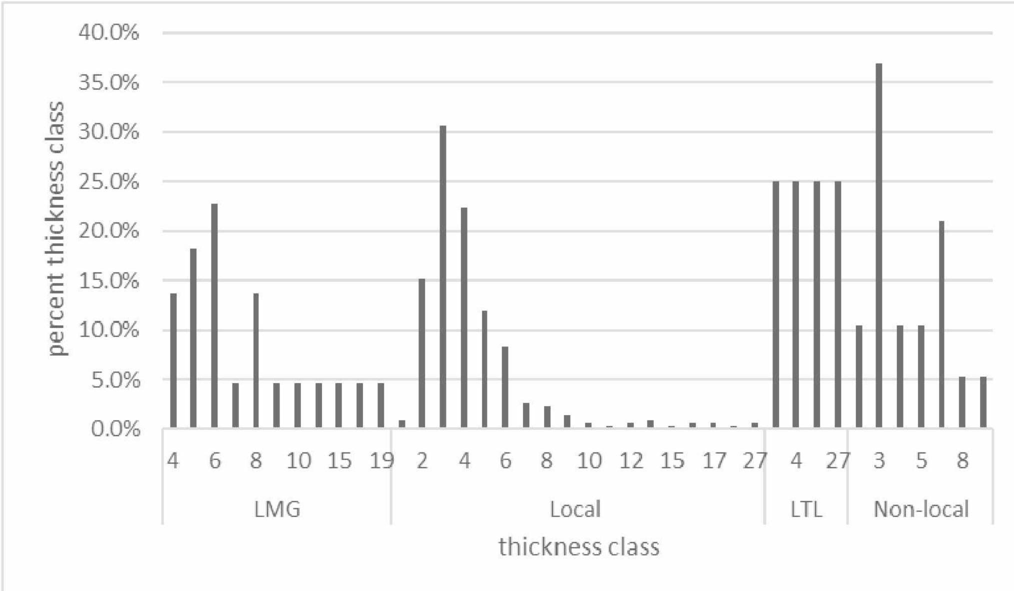

Figure 5.40 Distribution proportions of artifacts assigned to thickness classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Northern Archaic component of Whitmore Ridge. Cramer's V-square = 0.10

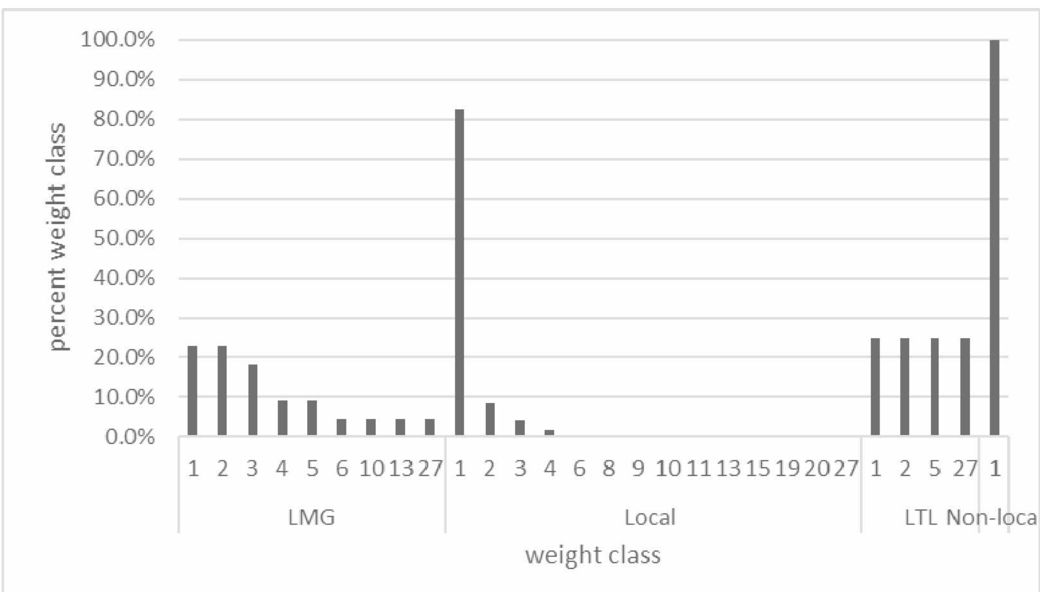

Figure 5.41 Distribution proportions of artifacts assigned to weight classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Northern Archaic component of Whitmore Ridge. Cramer's V-square = 0.10

Whitmore Ridge C1

Whitmore Ridge C1 is the only Denali Complex component and should be compared to the results of the lithic analysis for Whitmore Ridge C2 the Northern Archaic component. The first difference is that estimated non-local materials are not part of the Denali Complex component. The technological types are less varied in this component and the presence of decortication flakes is more widespread among materials (Table 5.29). Simple flakes are the greatest proportion of flakes for all the materials (Table 5.29). Long Tangle Lake has the closest proportion between simple (66.7%) and decortication flakes (33.3%) (Figure 5.2.67). Landmark Gap Quarry material has the widest difference in proportion between simple flakes (81.4%) and decortication flakes (18.6%) (Table 5.29). The estimated local materials have the most variation in technology, as it has both bifacial thinning flakes (1.8%) and a core part (0.9%).

The Landmark Gap Quarry material has a similar distribution of flake platforms as the estimated local material (Table 5.29). The Long Tangle Lake Quarry flakes with platforms are not terribly different given the sample size. Only two flakes have platforms, one is a complex platform and the other is simple. For the other two material groups, complex platforms are the majority of each associated sample (Table 5.29). The only main indication of difference between the estimated local materials and the Landmark Gap Quarry material at this site is that the local materials have flakes with crushed platforms (3.7%) (Table 5.29). Both the Landmark Gap Quarry material and the estimated local material group are dominated by flakes with complex platforms, 51.2% and 52.4% respectively (Table 5.29). Abraded platforms follow in proportion to the complex platforms for the Landmark Gap Quarry material (17.1%) (Table 5.29). The proportion of simple and abraded platforms are close for the estimated local material group, 18.5% and 19.6% respectively (Table 5.29). This suggests that both Landmark Gap Quarry material was used to produce tools and early stages of the reduction of the material also occurred due to the presence of cortical platforms (7.3%) (Table 5.29). However, there is similar use of local materials, which may actually be Landmark Gap Quarry material as well.

Between the two quarries there is a low amount of material with cortex. In fact, there are no flakes that have greater than 50% cortex (Table 5.29). This pattern for Landmark Gap Quarry is consistent throughout all the sites and all the components, which is reiterative of the possibility of the earliest stages of reduction required at the Landmark Gap Quarry due to the quality and form of the bedrock. The Long Lake Quarry cortex amount reveals that early reduction may have occurred at the site but it is unclear if complete nodule reduction occurred.

Flakes with all of the different dorsal scar count amounts are made of Landmark Gap Quarry material (Table 5.29). The number of flakes with dorsal scars increases as the number of dorsal scars increases, as 4.3% of the Landmark Gap Quarry flakes have no dorsal scars, and 47.1% of the flakes have more than 4 (Table 5.29). This suggests early through late stage reduction and tool production using the Landmark Gap Quarry material. Alternatively, the few flakes that are made of Long Tangle Lake Quarry material are 66.7% with four dorsal scars and 33.3% with greater than four dorsal scars (Table 5.29). Though the sample size is low, the tendency towards high dorsal scar counts may indicate later stage tool production on the Long Tangle Lake Quarry material.

The distribution of fragments, split, broken and complete flakes in Whitmore Ridge C1 is similar for both the Landmark Gap Quarry material and the estimated local materials, but different for Long Lake Quarry material (Table 5.29). The Long Lake Quarry material only contains flakes that are broken (66.7%) and a fragment (33.3%), (Table 5.29). The similarity in distributions between the Landmark Gap material and the estimated local material may suggest that some of the local materials are actually un-chemically analyzed Landmark Gap Quarry flakes. It also may suggest that local materials and the Landmark Gap Quarry were utilized more heavily during the Early Holocene.

The metric measures length and width have very similar distributions across the classes for each material (Figure 5.42, Figure 5.43). The variation in size class for the Landmark Gap Quarry material and the local material likely mimic the degree of variation in Sullivan and Rozen typology. There are no flakes in the smallest length classes 1 – 5, and the largest length classes 27-30 (Figure 5.42). Alternatively, there are flakes in every length class made of the estimated local material. The results of the length class are very similar to the other metric measurement classes. The thickness and weight classes have more positive skew toward the thinner and lighter classes (Figure 5.44, Figure 5.45).

Flakes made of the Landmark Gap Quarry material show mixed attributes indicating soft and hard hammer percussion. For instance, of the Landmark Gap Quarry material 44.2% of the flakes have erailure scars (Table 5.29), and 17.1 have lipping (Table 5.29), but only 42.2% have salient bulbs (Table 5.29). It would be expected that the proportion of salient bulbs (Table 5.29) was higher to indicate hard hammer percussion. But there is clearly a combination of percussion types used on this material. The proximal ended flakes from the Long Tangle Lake Quarry are with even proportions of erailure scars present and absent (Table 5.29), and salient and diffuse bulbs (Table 5.29). However, there are no flakes with lipping (Table 5.29). The estimated local materials show their own pattern of proximal end attributes, as 59.5% of the local material are flakes without erailure scars (Table 5.29), 73.0% have no lipping (Table 5.29), and 68.5% have diffuse bulbs of percussion (Table 5.29), suggesting both hard and soft hammer percussion was likely used on this material.

Table 5.29 Lithic attributes recorded on lithic debitage from for each material at the Denali component of Whitmore Ridge (C1). The Percent of total debitage sample of each material with particular attributes was calculated.

Attribute		% Landmark Gap Quarry	% Local	% Long Tangle Lake Quarry	% Non-local
cortex amount Cramer's V-square 0.00	none	80.0	78.2	66.7	0
	0-50%	20.0	21.2	33.3	0
	>50%	0	0.6	0	0
dorsal scar count Cramer's V-square 0.02	0	4.3	7.9	0	0
	1	8.6	4.9	0	0
	2	8.6	14.9	0	0
	3	14.3	17.6	0	0
	4	17.1	13.0	66.7	0
	>4	47.1	41.8	33.3	0
platform type Cramer's V-square 0.00	abraded	17.1	19.6	0	0
	complex	51.2	52.4	50.0	0
	cortical	7.3	5.8	0	0
	crushed	2.4	3.7	0	0
	simple	22.0	18.5	50.0	0
Sullivan and Rozen typology	broken	41.4	39.7	66.7	0
	complete	14.3	14.6	0	0

Cramer's V-square 0.00	fragment	42.9	42.1	33.3	0
	shatter	0	0	0	0
	split	1.4	3.6	0	0
flake type Cramer's V-square 0.00	bifacial thinning	0	1.8	0	0
	bipolar	0	0	0	0
	core part	0	0.9	0	0
	decortication	18.6	14.6	33.3	0
	modified flake	0	0	0	0
	shatter	0	0	0	0
	simple	81.4	82.7	66.7	0
erailure scar Cramer's V-square 0.01	present	44.2	40.5	50.0	0
	absent	55.8	59.5	50.0	0
lipping Cramer's V-square 0.01	present	17.1	27.0	100	0
	absent	82.9	73.0	0	0
bulb of percussion Cramer's V-square 0.01	salient	42.2	31.5	50.0	0
	diffuse	57.8	68.5	50.0	0

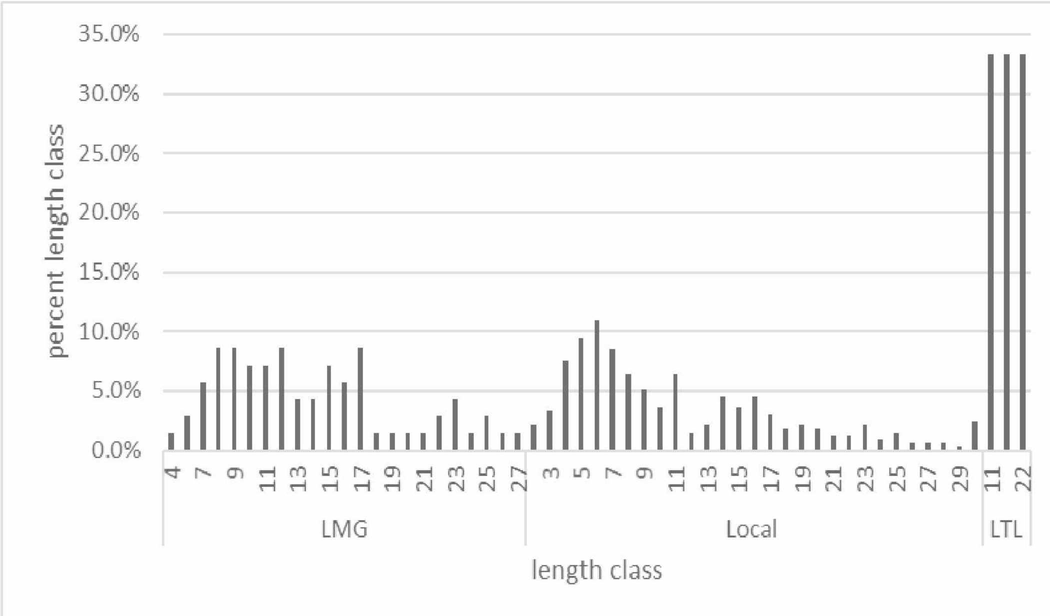

Figure 5.42 Distribution proportions of artifacts assigned to length classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Denali component of Whitmore Ridge. Cramer's V-square = 0.10

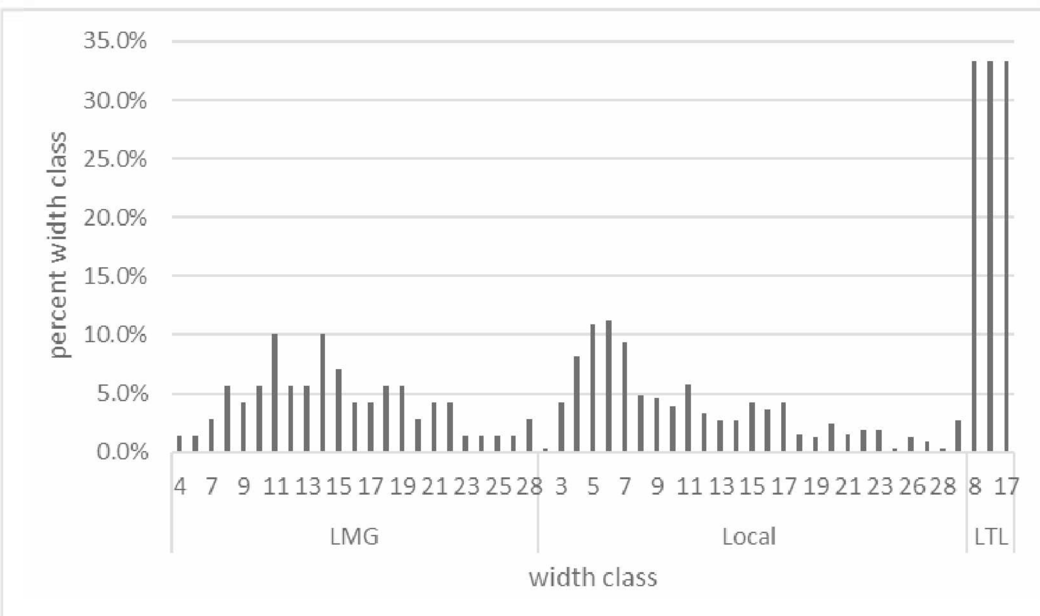

Figure 5.43 Distribution proportions of artifacts assigned to width classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Denali component of Whitmore Ridge. Cramer's V-square = 0.10

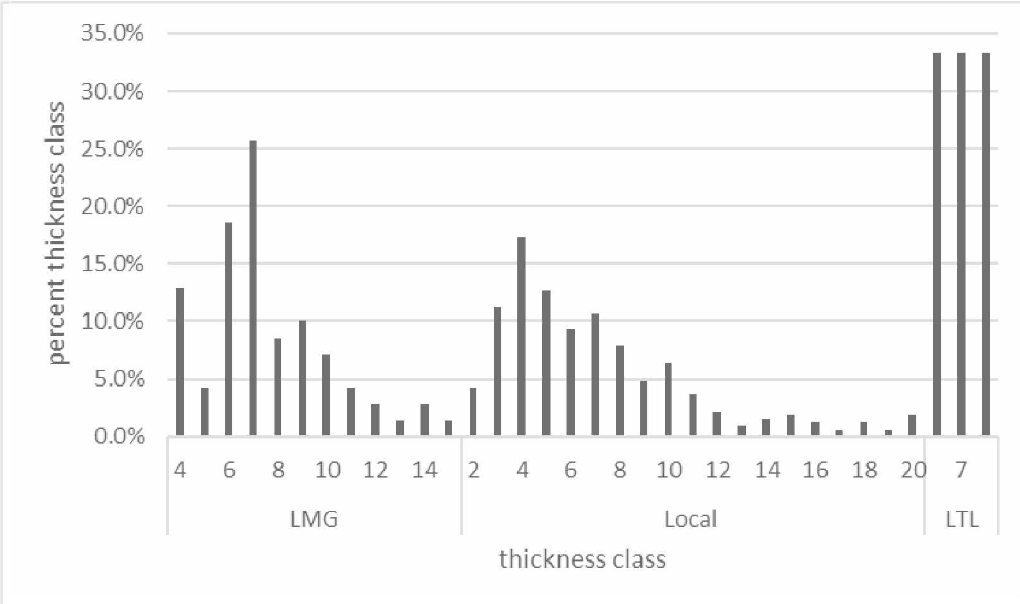

Figure 5.44 Distribution proportions of artifacts assigned to thickness classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Denali component of Whitmore Ridge. Cramer's V-square = 0.05

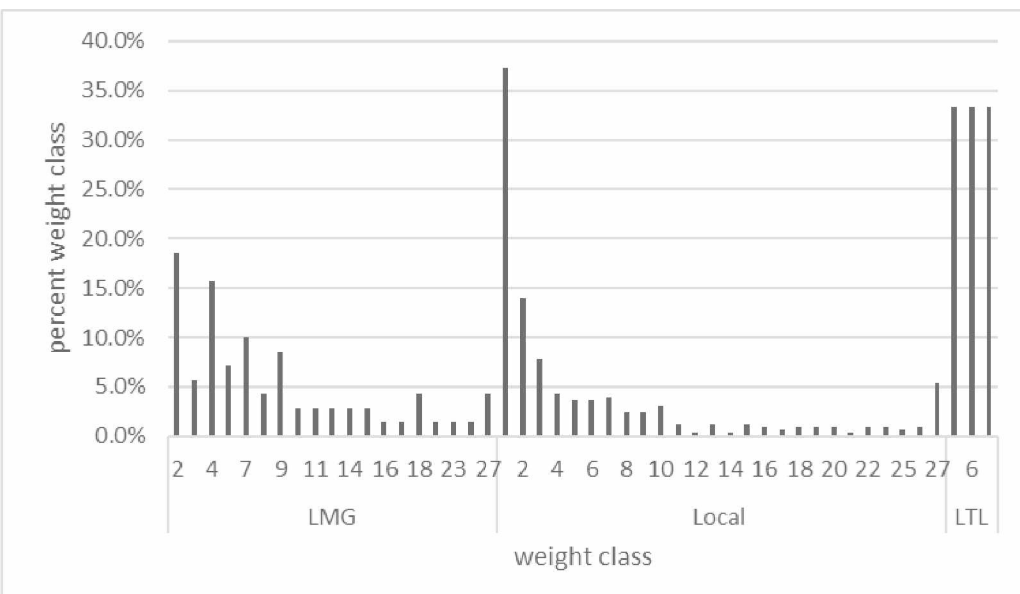

Figure 5.45 Distribution proportions of artifacts assigned to weight classes of Landmark Gap Quarry (LMG) and Long Tangle Lake Quarry (LTL) materials and local or non-local materials at the Denali component of Whitmore Ridge. Cramer's V-square = 0.13

To summarize the results of raw material distributions within each site component, patterns stood out for how the quarry materials were utilized at each site, including some apparent differences between the Whitmore Ridge site and the other Northern Archaic components, and between the Whitmore Ridge Denali component and Northern Archaic component. At XMH-35, Long Tangle Lake material showed signs of primarily being used for formal tool production, and particularly bifacial thinning. However, all stages of reduction including the initial nodule reduction and final tool production occur at the site. There is variety in what was produced on this material at the site. In contrast, at XMH-35 Landmark Gap Quarry material was reduced using bipolar techniques, and there was no bifacial thinning. However, there was also no nodule reduction of this material on site. There was not a clear type of tool being produced, though tool production was apparent. All stages of reduction except for initial nodule reduction likely occurred at this site. There are indications of tool production but of expedient tools.

Patterns at the Landmark Gap Trail Site with the Long Tangle Lake Quarry material show that there is a focus on tool production but also initial nodule reduction representing every stage of reduction and tool production. Bifacial sharpening and thinning are not a focus, therefore there is increased variation in tool production. On the other hand, the Landmark Gap Quarry material shows signs of bifacial thinning as well as expedient tool production. The lack of cortex and increase of a variety of platforms suggests a variety of tools were produced at the site but the first stage of nodule reduction was performed offsite.

Whitmore Ridge C2 Long Tangle Lake material also shows signs of all stages of reduction because of a high number of cortical flakes. It appears that both expedient tools and formal tools were produced, and specifically bifacial thinning. The Landmark Gap material may have also been reduced in entirety at the site, though less nodules were likely brought in at the earliest stage. Both, expedient and formals tools were likely produced.

In contrast to Whitmore Ridge C2, Whitmore Ridge C1 lacked signs of biface production on either one of the quarry materials. Whitmore Ridge C1 Long Tangle Lake material was mainly reduced from the initial nodule on-site and was used to produce expedient tools, and possibly some formal tools. Alternatively, a small amount of Landmark Gap Quarry material was likely reduced in entirety at the site but mainly was used to make a variety of tools, particularly formal tools.

Chapter 6: Discussion

6.1 Addressing Problems and Research Questions

The evaluation of local procurement and land use strategies at high resolution in the Tangle Lakes is not possible without compositional identification of local quarry material in lithic samples from Whitmore Ridge C1 and C2, XMH-35, and the Landmark Gap Trail site. Toolstone sourced to the Landmark Gap and Long Tangle Lake Quarries is compared to the patterns in estimated local and non-local material to evaluate if the quarries were treated differently. For instance, it appears that Long Tangle Lake Quarry material was treated more like a non-local material than a local material. Several levels of analysis tease procurement strategies out of the archaeological data. First proportions of estimated local and non-local material, and Landmark Gap Quarry and Long Tangle Lake Quarry materials are quantified for each site. The site type/function likely influences how raw materials were used and acquired. Therefore, technological activities that took place at each site are established before interpreting raw material and technology type distribution. The debitage analysis is able to predict activities that took place at the site, which is compared to interpretations of site type in existing literature largely based off of tool analysis. Specific uses of raw materials are evaluated in relation to the activities that occurred at each site to provide a complete picture to understand reasons for particular raw material strategies. Ultimately, the results were able to address the seven questions posed in this research:

(1) What types of activities were performed at each site component?

(2) Is there differential treatment of raw materials in each component?

(3) How does the treatment of the Tangle Lakes Quarry material and the Landmark Gap Quarry material compare to the estimated local and non-local materials in each component?

(4) What procurement strategies can be identified for each site component?

(5) Are mobility and procurement strategies different through time?

(6) Does site type consistently influence procurement and mobility?

(7) how do the technological strategies employed at these sites fit into the broader context of Early through Mid-Holocene human behavior in central Alaska?

The lines of evidence used to answer these questions are on lithic technology because it is the most abundant source of data from the site components in this study. Two additional lines of evidence that could provide a richer understanding of subsistence practices and intra-site activities are more provenienced data and a faunal analysis. These data could parallel results from lithic technological studies but may only be possible with additional site excavation. Individual flake attribute analysis of debitage assemblages provided behavioral links for interpreting static lithic objects. Compositional finger-printing of artifacts and their respective sources provided a spatial line of evidence which connects static lithic objects to their transport and human mobility. The behavioral interpretations of the results will be discussed in the following sections.

6.2 Validity of Artifact Source Assignments

The ability to chemically source artifacts and define source groups is a data reduction technique intended to summarize chemical variation in the bedrock material and the artifacts made from it. Every step of analysis that led from determining the geologic definition of the quarry material to assigning associated artifacts is quantitative and can be tracked statistically. However, the nature of chemically "sourcing" artifacts is largely theoretical. It is argued that nothing is 'truly' sourced, but rather stone sourcing is a statistical probability and only varying degrees of probability can be achieved for determining the actual source of material on the landscape (Pitblado et al. 2008; Shackley 1998). Compositional analysis provided multidimensional compositional concentration units which must be reliably and validly assigned to geographic coordinates to determine a "source;" the compositional units themselves are not oriented in space. Furthermore, simply determining the source of a material does not address human behavior, because the only information provided from "sourcing" is the "measure of physical displacement of materials" (Hughes 1998). This research not only rigorously provides these data points (compositional groups of artifacts assigned to a source, and source location), but also evaluates them in conjunction with additional lines of archaeological evidence to understand prehistoric behavior, such as others have discussed material procurement (Beck et al. 2002), mobility (Jones et al. 2003, 2012), exchange (Ogburn 2011), and social interaction (Phillips and Speakman 2009; Smith et al. 2007).

Having a reliable quantitative basis upon which to establish source locations and artifact assignments is paramount to making any sort of valid archaeological claims. The chemical data that was collected was tested for accuracy and precision, providing both internal and external consistency in every stage of application. The stages included:

(1) sampling for intra-quarry homogeneity and inter-quarry heterogeneity,

(2) ensuring no bias based on analytical surface flatness and sample thickness,

(3) correctly quantifying spectra obtained on the WD-XRF to ensure every element that was in each sample was represented,

(4) selecting an appropriate non-destructive analytical device and software to chemically analyze the artifacts,

(5) correctly calibrating the device in order to capture and quantify the spectra in terms of parts per million on the non-destructive analyzer,

(6) testing the accuracy and precision of the non-destructive device on UAF standards,

(7) testing the accuracy of analyzing non-flat and cortical surfaces on the non-destructive analyzer,

(8) analyzing artifacts from assemblage samples that are of the appropriate diameter and thickness to cover the X-ray beam,

(9) analyzing each artifact three times to ensure compositional variability of each lithic is captured,

(10) using multivariate statistics to determine the group association of artifacts with sources.

This ten-step outline represents a “best practice” procedure for sourcing artifacts to known quarries.

The ability to destructively analyze the material from two geologically discrete quarries that are vetted prehistoric sources provided an avenue for this approach. Essentially, this method excluded the possibility that any qualitative guess work be incorporated in the quantitative distinctions of the quarry material. Therefore, artifacts that chemically fell into the distinguishing range of quarry values could statistically be assigned to the respective quarries. The quantitative rigor incorporated into defining the geological material and calibrating the analytical devices ensures internal and external validity of artifact assignments, which is often not found in other archaeological sourcing studies that only use stock calibrations on non-destructive portable x-ray fluorescence spectrometers. Without the analytically rigorous procedures to define, distinguish true quarry groups, and assign artifacts to the groups allows sourcing of artifacts in the debitage assemblages in this study to be accepted as true representations of where the material originated.

The compositional sourcing analysis cannot account for the probability of the quarry material entering the archaeological record in secondary source contexts (e.g. rivers and alluvium). The nature of the location of the Long Tangle Lake Quarry and the Landmark Gap Quarry excludes much variation in where the material could have traveled via waterways. For instance, the Landmark Gap Quarry is a distinct knoll with exposed nodules of fine grained material and does not erode into a river. The Long Tangle Lake Quarry material could erode into an adjacent creek, but the material would go as far as Long Tangle Lake, which has only a very slight current, that would likely not carry the nodules far. Therefore, the Long Tangle Lake material could only naturally be displaced by approximately 2km to the southwest of the quarry itself. Therefore, in the broad context of the study, the possible displacement is negligible for understand human behavior. Furthermore, knapping on the bedrock of the quarries themselves and surficial artifacts nearby suggest that material was obtained specifically at the quarries.

6.3 Technological Organization and Lithic Procurement

Technological organization applies patterns of toolstone reduction and spatial distribution of technology as a framework to understand the behavioral mechanisms that drive each stage of raw material acquisition, toolstone transport, toolstone reduction, tool production, and discard. The compositional sourcing data provided the spatial point of origin with which to evaluate the distribution of the lithic materials in this study, and a basis for making local and non-local estimations for unknown materials. The overall availability of materials in the Tangle Lakes study area will be discussed in an effort to address the research questions. This is consideration of how different materials are treated at each site with regards to site type. This will introduce a discussion of toolstone procurement strategies that area based on how the materials were being used at each site. The procurement strategies that are discussed for each component can be compared within the Northern Archaic component and between the Denali Component and Northern Archaic component at Whitmore Ridge to understand differences in procurement strategies based on site type, location, and time period.

6.4 Availability of Materials

Availability of materials can be measured in terms of abundance and attractiveness based on the physical bedrock attributes of each quarry. This availability information may be compared to ratios of each quarry material at the sites. Amount of different qualifiers about the material, such as overall material quality, presence of local and non-local material, and different rock types in assemblages can also be used to understand potential availability of material on the landscape in terms of how it was being used at each site. The validity of raw material type groupings based off of visual analysis are completely unreliable to distinguish distinct sources on the landscape where material originated. However, it is possible that visually identified raw material groups may be an acceptable reduction technique to evaluate material manufacturing qualities and preference. Additionally, aggregate visual raw material groups may be regrouped into useful broader estimated spatial categories, such as general raw material proximity (local v. nonlocal) based on cortex amount, dorsal scar count, flake amount, and flake size. It is safe to assume that the local and nonlocal groupings assigned to individual artifacts are accurate based on the definition of local being within the Tangle Lakes Archaeological District boundary and non-local as outside the district boundary.

Several measures were used to evaluate differences in availability, and abundance, as well as delineate expectations for toolstone preference based on the bedrock quarry material at the Long Tangle Lake Quarry and the Landmark Gap Quarry, all else being equal. To accomplish this, other aspects that affect preference were held constant to develop expectations concerning the type of technology being produced and site type. For instance, certain raw material qualities may be more favorable for production and function of certain technologies over others, such as bifacial production verses microblade production. The measures of availability and attractiveness were focused on the qualities and features relating to the Landmark Gap Quarry and the Long Tangle Lake Quarry. Four measures were used to develop expectations to assess the amount of these materials in the lithic assemblages. These measures were: (1) the Quarry Abundance Ratio, (2) gravity/attractiveness model, (3) relative cost of travel between each site and source, and (4) Euclidean distance between site and source.

The Quarry Abundance Ratio is based solely on the quantitative characteristics of each quarry and does not incorporate assumptions about human efficiency or preference. It is a ratio of the maximum material available from both quarries. The ratio suggests there is more Long Tangle Lake material available on the landscape. Therefore, it is expected that the proportional ratio of Long Tangle Lake Quarry material to Landmark Gap Quarry material seen on the landscape will also be reflected in each assemblage. Brantingham (2003) discusses expectations for a neutral model of procurement based on the ratio of material availability on the landscape, which Soto et al. (2017) applies to the Chert Abundance Ratio. The expectations for a neutral model of procurement in relation to the Quarry Abundance Ratio is: overall there will be no significant difference between the QAR and proportions of the materials in the sites; therefore, if ratios of the Long Tangle Lake Quarry material to Landmark Gap Quarry material are similar to the QAR = 2.59, then material availability likely dictated the amounts of material in the lithic assemblage. If material ratios in the assemblages are different from the QAR value, then it is likely that other factors were influencing the selection of material, such that people were employing selectionist procurement strategies (Brantingham 2003; Soto et al. 2017).

Based on these expectations, the results obtained in this study show that the closer Landmark Gap Quarry material was likely selectively procured at the Landmark Gap Trail Site despite the ratio of materials at the site being the closest to the QAR; however, human agents at XMH-35, and Whitmore Ridge C1 (Denali) and C2 (Northern Archaic) clearly appear to have employed a selectionist procurement strategy. The ratio of Long Tangle Lake Quarry material to Landmark Gap Quarry material at the Landmark Gap Trail site differs the least from the QAR, but in favor of the Landmark Gap Quarry material. However, when the proportion of the Long Tangle Lake Quarry material at the site is considered, it is clear that humans at this site were acquiring the Long Tangle Lake Quarry material in large proportions, despite its high cost.

Based on the expectations for the QAR model, XMH-35 shows a selectionist pattern in favor of the Long Tangle Lake Quarry material. On the other hand, both Whitmore Ridge C1 and C2 show a selectionist pattern for the Landmark Gap Quarry material. Evaluation of other factors that influence such as overall quarry attractiveness, distance, and cost of transport, as well as lithic technology and site activities associated with each material may explain the neutral and selectionist procurement patterns at these sites.

The next measure of material availability in terms of how it may be distributed within the site assemblages is Euclidean distance for roundtrip travel between each quarry and each site. This model assumes that distance is the main conditioning factor of material procurement. The proportion of each of the quarry materials in each site can be evaluated based on the Euclidean distances between each site and quarry according to expectations of distance-decay models (Beck 2008; Blumenschine et al. 2008; Brantingham 2003; Renfrew 1977). All else being equal, it is expected that sites closest to each respective quarry will have more of the closest quarry's material and less material of the quarry that is farther away. All of the sites are south of both of the quarries. The Landmark Gap Quarry is closer to all the sites than the Long Tangle Lake Quarry. Therefore, it is expected that there will be more Landmark Gap Quarry material than Long Tangle Lake Quarry material at each site. Both the Denali and Northern Archaic components at Whitmore Ridge clearly adheres to these expectations. The Landmark Gap Trail site meets distance-decay expectations. It is closer to the Landmark Gap Quarry than the Long Tangle Lake Quarry by 6.4km. However, it is surprising based on the proximity of the Landmark Gap Trail site to the Landmark Gap Quarry that there is an almost equal proportion of Long Tangle Lake Quarry material at the site. The QAR comparison suggests selective procurement of the Landmark Gap Quarry material at the Landmark Gap Trail site, which is likely because the site is so close to this quarry as observed through the distance-decay model. The close to equal proportion of the Long Tangle Lake Quarry material to Landmark Gap Quarry material at the site despite the distance to travel round trip between the quarry and site to procure the Long Tangle Lake Quarry material suggests that an embedded procurement strategy was employed. If embedded procurement was practiced at the site the acquisition of the Long Tangle Lake Quarry material may not accrue any additional cost. XMH-35 does not meet the expectations of the distance-decay model, which is another line of evidence that confirms the selectionist procurement model for XMH-35 acquisition of Long Tangle Lake Quarry material. Even though the Long Tangle Lake material is farther away it is a larger part of the assemblage than Landmark Gap Quarry material. This could also be evidence of an embedded procurement strategy at XMH-35 because distance is not the main conditioning factor of embedded procurement. Whitmore Ridge C2 and C1 clearly meet expectations for the distance-decay model which adds to the site meeting the selectionist expectations from the QAR model. It affirms that Landmark Gap Quarry material was closer to Whitmore Ridge and was preferred over the Long Tangle Lake material, which may be evidence for a direct procurement strategy.

The third model evaluated movement between the quarries and the sites is based on roundtrip cost. This model expects that cost of travel is the main conditioning factor of material procurement. Cost is calculated based on slope, distance, and advantages and barriers associated with water travel.

Because the quarries would likely have been buried in snow a large portion of the time that water was frozen, open water may have served as a significant friction factor. The expectations for the model are the same as the distance-decay model, with the general assumption that prehistoric people would have acted efficiently to minimize the cost of transporting material across the landscape. The cost distance values mirror the distances between the sites and quarries, such that the Long Tangle Lake Quarry material is much more costly to obtain than the Landmark Gap Quarry material for all of the sites considered. The most apparent difference in the two models is that transporting Long Tangle Lake Quarry material to and from the Landmark Gap Trail site is much more costly than transporting Long Tangle Lake Quarry material to and from Whitmore Ridge. Based on this information it is surprising that there is a higher proportion of the Long Tangle Lake Quarry material at the Landmark Gap Trail site than both components at Whitmore Ridge. The results obtained provide more evidence for selectionist treatment and direct procurement of Landmark Gap Quarry material at Whitmore Ridge C1 and C2. It also provides more evidence for embedded procurement of Long Tangle Lake Quarry material at Landmark Gap Trail site. The cost of transport model shows that there was selective treatment and possible embedded procurement of Long Tangle Lake Quarry material at XMH-35.

The final attractiveness/gravity model provides additional evidence for the patterns described above and a potential understanding of why these patterns emerged. Relative attractiveness values were calculated for each of quarries based on the positively incentivizing variables: material quality, extent of the source, size of nodules; and negative values: difficulty of terrain, cost of extraction, and scarcity. The difficulty of terrain is the same value as the round trip cost calculated between each quarry and each site. As such, the model attempts to incorporate factors that would restrict or act on human decision-making assuming that people acted rationally to maximize energy efficiency (Taliaferro et al. 2010; Wilson 2007a, 2007b). Based on the attractiveness equation, the higher the attractiveness value the more "attractive" the source is, in relation to each site. According to the model, the Long Tangle Lake Quarry is more attractive than the Landmark Gap Quarry for all of the sites considered, despite the cost distance. Therefore, the model provides evidence that despite being more costly to transport material, overall aspects of the Long Tangle Lake Quarry may make it more attractive in terms of total cost efficiency. This model, again, confirms the previous patterns stated about the acquisition of Long Tangle Lake material at XMH-35. It is reiterated in all the models, especially the attractiveness model that there was preference for and selective procurement of the Long Tangle Lake Quarry material at

XMH-35, likely through means of embedded procurement. Landmark Gap Trail site had slightly opposing patterns based on the different models that are clarified by the final attractiveness model. The QAR model suggested that the Landmark Gap Quarry materials were preferentially procured at the Landmark Gap Trail site; however the attractiveness model suggests that the Long Tangle Lake Quarry material was also desired as it occurred at this site almost equal in proportion with the Landmark Gap Quarry material. According to the attractiveness model, the Long Tangle Lake Quarry material is much more "attractive" than the Landmark Gap Quarry material at the Landmark Gap Trail site, despite being much farther away and subsequently more costly to get to. Therefore, the procurement of Long Tangle Lake Quarry material taking place at the Landmark Gap Trail site was likely by means of embedded procurement, to minimize or eliminate a cost associated with its procurement (Bamforth 2006). Whitmore Ridge C1 and C2 are the only two components that do not meet the expectations of the attractiveness model, such that there are higher proportions of Landmark Gap Quarry material in each component, despite the Long Tangle Lake Quarry material being more attractive. However, these components meet the expectations of the distance and cost of transport models. Therefore, it is likely that the Landmark Gap Quarry material was preferentially selected at this site and was directly procured. Direct procurement is expected to be conditioned the most by distance of transport, and therefore align more with distance-decay models (Surovell 2009a).

6.5 Diversity Indices

Measures of material availability evaluated the raw material on the landscape in terms of what is expected to be in the assemblages. Diversity indices are useful for measuring occurrence of materials within assemblages. This can add to the evaluation of how materials were incorporated into the assemblages based on the availability measures. Raw material diversity and evenness have been shown to be associated with procurement strategies (Clarkson 2008). It has been used specifically to differentiate between embedded and direct procurement strategies. Material diversity, specifically high material diversity, could also be associated with materials entering the site via trade. However compositionally sourcing artifacts to known non-local sources, such as Batza Tena or Wiki Peak obsidian would be the best way to identify trade. Therefore, evaluation of diversity measures for each site component provides an additional line of evidence to evaluate with the four independent distributional models to supports the discussion of embedded and direct procurement of Long Tangle Lake and Landmark Gap Quarry materials in the local study area. The expectations for raw material diversity in assemblages are as follows: increased material diversity and high evenness is indicative of embedded procurement strategy, such that a number of materials are acquired in the subsistence round, thus the farther people travel to acquire resources the more likely they are to come across material that could be transported back to the site in the form of a nodule, a reduced/prepared nodule or biface, or as a used tool that could be resharpened at the site or reused for another purpose. Therefore, embedded procurement would likely be represented by a diverse set of raw materials entering the archaeological debitage assemblage in a number of different technological forms. Alternatively, direct procurement is often recognized by low diversity and low evenness, such that one particular material is overrepresented, and there is lack of many other materials. This is a result of people going to a raw material source for the sole reason of procuring raw material nodules for knapping. The reduction prior to coming into the site by means of direct procurement is usually highly correlated with the distance-decay model.

The diversity and evenness measures adhere to the expectation that raw materials were incorporated into the XMH-35 assemblage through embedded procurement. XMH-35 has the highest diversity and evenness values of all the components. The Landmark Gap Trail site has the second highest diversity and evenness values. These values suggest that embedded procurement was the mechanism for bringing materials to this site, which reiterates the embedded procurement of the costly but more attractive Long Tangle Lake Quarry material at the site. The costly distances may be null because if the Long Tangle Lake Quarry material was acquired through embedded procurement while obtaining other subsistence resources in the area, thus this strategy could lower the overall cost of acquiring the material (Binford 1980; Seeman 1994). Based on the combination of all the information, it is likely that at Landmark Gap Trail site materials were obtained through embedded procurement. The proximity of the Landmark Gap Trail site to the Landmark Gap Quarry in the embedded procurement system may account for slightly higher Landmark Gap Quarry material than the Long Tangle Lake Quarry material. Similarly, at XMH-35 materials were likely introduced to the site via embedded procurement practices, but the Long Tangle Lake Quarry material was preferred overall or most frequently visited in subsistence activities. Whitmore Ridge C2 has the lowest diversity and evenness values of all the components suggesting a direct procurement strategy, particularly of Landmark Gap material, that did not allow for incorporation of many other materials into the assemblage. Whitmore Ridge C1 (the Denali Component) mimics the same procurement strategy at Whitmore Ridge C2, though there was slightly higher material diversity and evenness. This suggests the site's location and general activities may have remained the same through time but the ways in which people used the landscape may have changed slightly.

6.6 Site Type Influence on Procurement

The site type, such as whether the site was a short term hunting camp, multi-occupation seasonal spike camp, or a long occupation of a residential site, can influence the understanding of how and why raw materials were procured. The technological patterns, such as presence of nodule reduction and tool production, and resharpening in each site component can illuminate how the site fits into the broader context of landscape use and mobility. The frequencies of technological attributes on flakes in the debitage assemblages can be indicative of general technological patterns at each site. The attributes that were used to highlight recurrent patterns in each assemblage were cortex amount, flake type, dorsal scar count, platform type, Sullivan and Rozen flake completeness typology, length class, width class, thickness class, weight class, and proximal end attributes: erailure scar, lipping, and bulb of percussion type.

The frequencies of each flake attribute show a clear pattern in technological strategies of a component associated with the Northern Archaic residence, XMH-35. All stages of reduction occurred at the site, though there was a clear bias towards late stage reduction. Concurrently, there were strong indications of tool production and maintenance. There was variation in the type of technology produced and the manner in which it was reduced, with specific emphasis on bifacial technology. There are signs of time investment in tool manufacture by platform preparation, and material conservation by bipolar reduction and biface maintenance. Literature and previous examination of the tools at the site has provided a background understanding of the activities occurring at the site (Robinson 2003). The site has the highest proportion of bifaces among sites with notched bifaces in the Tangle Lakes region (n = 201 with 124, 62% well-thinned), (Robinson 2003). The tools at the site provide the same conclusion as the debitage; that of biface production with less prevalent early stages of biface production (Robinson 2003). The site was likely occupied intensively for a period of approximately 1,000 years during the Mid-Holocene. The technology situates it within the Northern Archaic technological complex. The period of intense occupation permitted the site's inhabitants to map on and learn the Tangle Lakes resource-rich landscape. Thus, the residence could remain unmoved while subsistence and lithic resources were acquired in the local area.

The most distinguishing features of the site include a house feature with post holes and a hearth (Robinson 2003). The only identifiable bone from the level III assemblage was a single cervid bone, likely from a limb. Three bones were identified with cut marks and the majority of bones (n = 49) were calcined, while only three bones were unburned. Despite the small amount of faunal remains at the site, the presence of burned bones and a hearth, as well as a house depression provides almost certain evidence for this being a residential site. A number of activities likely took place at the site, from cooking, meat and hide processing, tool production and maintenance, gearing up for logistical subsistence forays, and nodule and expedient tool reduction for activities around the site. The variety of activities that are expected to occur at a residential site is represented by the variety of technology associated with the debitage assemblage. It is likely that embedded procurement strategies brought a variety of material into the site in conjunction with logistical subsistence forays. Expedient tools may have been produced from materials that were immediately available near the site.

The Northern Archaic occupation at Landmark Gap Trail site may have been contemporaneous with the occupation at XMH-35, because the radiocarbon dates from these components overlap. Based on the redundancy of testing independent models it likely that materials were acquired via embedded procurement at the Landmark Gap Trail site. Therefore, it is possible that the same people that inhabited the residential site (XMH-35) were visiting the Landmark Gap Trail site during subsistence forays and embedded procurement round. This hypothesis can be evaluated by the activities that took place at the Landmark Gap Trail site. The debitage assemblage attribute patterns clearly show that all stages of reduction took place at the site, but in contrast to XMH-35, there was a preference towards early stages of reduction. While, more indicators of soft hammer percussion were present at XMH-35, there were more indicators of hard hammer percussion at the Landmark Gap Trail site. Though there is a tendency towards nodule reduction and early stage reduction, the cases that make it seem like all stages of reduction were occurring at the Landmark Gap Trail site include instances of biface maintenance and some tool production.

The Landmark Gap Trial site debitage sample was taken from a Feature 1 – a hearth, directly associated with a radiocarbon date of 4330+/-125 B.P., interpreted as a single construction/use event (Mobley 1982). The site has a varied distribution of lithic debitage across the site in Level II (most closely related to the radiocarbon date in Feature 1) but the most dense concentrations are within the features, suggesting localized areas for tool production and maintenance (Mobley 1982). There were 6110 lithic artifacts collected from all the layers of the Landmark Gap Trail site in 1980, and 5000 artifacts were associated with Feature 1. There were 11 bifaces recovered from the site, represented by 13 lithic pieces. The site assemblage also contains retouched tools. Based on site location and initial analysis of the site-wide lithic assemblage, Mobley (1982) hypothesized that this site was strategically placed for large game procurement since the Landmark Gap valley could have been a corridor for caribou and moose, as it still is. Though the site is in modern moose range, it is likely that caribou were the main subsistence resource at the time the site was occupied (de Laguna and McClellan 1981; Reckord 1983; Yesner 1989). Only one of the bifaces of the site has been called "functionally specialized" for hunting, though the other bifaces at the site could have been used for hunting if necessary (Mobley 1982). According to Mobley (1982), the site was likely focused towards biface production and meat processing, rather than hunting being the focus of the site. The presence of the hearth, Feature 1, could be indicative of time investment into the site suggesting reoccurring site occupation. Bifaces are also a form of a raw material package than could be transported elsewhere in a useable form but without the additional cortex of a whole nodule (Larson 1994). Mobley (1982) recognized low material diversity in the debitage assemblage at the site overall, with most material diversity occurring in the tool assemblage. Mobley (1982) assumes materials were probably procured from the Landmark Gap Quarry only 3km away, however this research shows otherwise. Instead, almost an even amount of material was procured from the Long Tangle Lake Quarry located some 8.8km away. The previous understanding of the site and the new lithic debitage analysis provide the same conclusions that the site was specialized for early nodule reduction and tool production. It is likely that bifaces were produced as a package for transporting raw material within the subsistence round through embedded procurement and was a stop along the logistical forays that were performed by the inhabitants of XMH-35. The late stage biface maintenance and lack of early stage reduction is likely a result of bifaces having been produced as a raw material package at the Landmark Gap Trail site or another similarly purposed location and brought to XMH-35. The Landmark Gap Trail site debitage assemblage and tool assemblage together confirm previous suggestions of material entering the site though embedded procurement adding slightly to the diversity of a relatively specialized stop-over site within a larger subsistence round.

The Whitmore Ridge site contains both an older Denali component (C1) and a younger Northern Archaic component (C2). First the Northern Archaic component will be discussed as it fits in with the other Northern Archaic sites (XMH-35 and the Landmark Gap Trail site). Whitmore Ridge C2, is a

Northern Archaic component; however the component date is slightly older than XMH-35 and Landmark Gap Trail site, suggesting that the site may not have been occupied at the same time as the others. On the other hand, it is unlikely that the site would have been abandoned at the date it was occupied (5143 +/- 199 B.P.); therefore temporal overlap in later occupation with the other Northern Archaic sites is also possible. Whitmore Ridge C2 debitage assemblage has a slightly more convoluted pattern when trying to tease out reduction stage and tool production processes. Ultimately, it is apparent that all stages of reduction were occurring relatively evenly, and tools were being produced and maintained. The balance of activities performed at this site, as per the debitage, must be considered in reference to the suggested selective procurement of Landmark Gap Quarry material, and possibility that it was directly procured. The site type may illuminate reasons for these strategies in contrast to the other Northern Archaic components.

Whitmore Ridge C2 has been characterized by looking at the tools produced at the site as a conchoidal core and blade industry different from the Denali Complex, including biface fragments and one burin (West et al. 1996). The component is interpreted as preferential use of lithic associated with core and blade technologies for a relatively brief amount of time (West et al. 1996). West et al. (1996) interprets the site as a short seasonal hunting occupation. Part of this interpretation is based on its location on a high esker, though providing a good game lookout point. Its upland setting could also indicate use anytime from Spring through Fall, especially during caribou migrations (Potter 2008b, 2008c). This would be consistent with interpretation of the lithic assemblage representing a short-term seasonal activity, while the site was maintained as an important hunting location through time due to repeated occupation from the Early through Mid-Holocene. Due to the specialized location of the site, it may have been occupied for the specific purpose of hunting, and travel to the site would necessitate a consistence material source to perform the activities and make reliable tools. All lines of evidence including the previous understanding of the site and tool analysis, the debitage attribute analysis, and material distribution assessment determined the direct procurement strategy selecting for Landmark Gap Quarry material at Whitmore Ridge C2, which is also consistent with the site component's hypothesized site function. If the site was specifically inhabited seasonally, during Fall through Spring months as a particularly well-known or optimal hunting site, then it would be likely that the closest reliable raw material source would be exploited to maximize time spent waiting for game. As long as the Landmark Gap Quarry is not covered in snow, material could have been directly and consistently procured with no risk of weapon failure or missing an opportunity to hunt game while searching for a material source. This is a potential explanation for direct procurement of the material and minimized material diversity. It is possible that the occupation of the Whitmore Ridge site later overlapped with the occupants of the Landmark Gap Trail site and XMH-35. If so, it is possible that the Northern Archaic component at Whitmore Ridge became a seasonal logistical camp that was specialized site but part of the same mobility and subsistence strategies as the populations occupying XMH-35 and the Landmark Gap Trail site. Alternatively, the patterns at the Northern Archaic component at Whitmore Ridge could be the result of a different population with a different subsistence strategy entirely. In this case, the site could have been a seasonal camp associated with a highly residentially mobile strategy, possibly carried over from earlier Denali occupants, that obtained all the subsistence and lithic resource from directly nearby the site but differential access to other materials such as the Long Tangle Lake Quarry material.

Whitmore Ridge C1 is associated with the Denali Complex and is an Early Holocene assemblage; therefore it is completely temporally and spatially distinct from the Landmark Gap Trail site and XMH-35, and temporally distinct from Whitmore Ridge C2. Whitmore Ridge C1, locus 3 is a lithic concentration directly associated with an Early Holocene radiocarbon date (10,279 +/-79 B.P.). West et al. (1996) suggest that the overall technological analysis of Whitmore Ridge C1, locus 3, including tools and debitage shows an unusual amount of bifacial technological features for a Denali Complex assemblage. The debitage analysis from the sample selected for this research suggests that the amount of bifacial production and maintenance, though present, was far less than that seen in the other Northern Archaic sites. In West et al.'s (1996) analysis, it is possible that the presence of indicators of bifacial technology in Whitmore Ridge C1 was inflated when compared to other Denali sites, but when compared to Northern Archaic components, bifacial technology does not seem to have been the main focus of the technological strategy. A typical "Denali core" and articulating notch flakes, and microblades are also associated with Locus 3, therefore; it is considered representative of a Denali Complex component (West et al. 1996).

The debitage sample analysis from Whitmore Ridge C1, Locus 3 had complex results for distinguishing technological strategies. All the metric measures tended to show that all stages of reduction occurred at the site with an emphasis on early stage reduction, while the non-metric attribute variables suggested that all stages of reduction were present but there was more of a focus on late stage reduction and tool production. It is consistent that all stages of reduction took place at the site, and that there was less bifacial tool maintenance than all of the Northern Archaic components. The technological difference, such that there was a focus on microcore and microblade technological strategy could be a reason for the convoluted patterns in the lithic debitage that does not include an analysis of microblades. It is safe to assume that the site was a location of tool and weapon production that incorporated early nodule reduction and preparation and tool production. The interpretation of procurement strategy and site function is the same for the Denali Component as it is for the Northern Archaic component because the site location and patterns of material are constant. The greatest difference in material distribution between Whitmore Ridge C1 and C2 is that there is a small proportion of non-local material (4.81%) in C2, while there is no non-local material in the C1. Therefore, the site was likely a specialized summer season Denali hunting lookout, where Landmark Gap Quarry material was procured directly, and augmented by other local materials. The duration of repeated occupation of Whitmore Ridge and use for the same function could have allowed for increased landscape familiarity through time and adjustments in overall landscape use strategies that allowed for incorporation of a small amount of non-local material during the Northern Archaic component.

Because it appears that Whitmore Ridge had the same function during the Early Holocene as it did during the Mid-Holocene and procurement strategies did not change, understanding how the site fits into the general expectations for landscape use with Denali complex technology verses Northern Archaic technology will likely be helpful for understanding the differences in how the site fits into the seasonal round. It is hypothesized that during the Denali component that Whitmore Ridge C1 represented a seasonal hunting site that was part of a residentially mobile strategy associated with initial mapping on the resource landscape and hence was associated with less landscape knowledge, but with longer distance movements following particular seasonal resources.

6.7 Site Technological Strategies and Material Type

The final line of evidence evaluated in order to show patterns in raw material procurement is technological type associated with raw material type in each component. This approach may fill in gaps of understanding procurement strategies based on inter-site comparison, while more detail may be evaluated through intra-site analysis of materials and technology. Patterns of raw material use stood out in each site component, especially clear patterns between Landmark Gap Quarry material and Long Tangle Lake Quarry material.

At XMH-35, Long Tangle Lake Quarry material was present for all stages of reduction, suggesting that nodules were reduced at the site. However, there were clear indications that the primary use of the Long Tangle Lake Quarry material was for tool production and bifacial tool maintenance. Two of the most apparent patterns that stood out for this material at XMH-35 are that there is no sign of initial nodule reduction and there is no bifacial thinning. Despite some flakes made of the Landmark Gap Quarry material were produced through bipolar techniques, there were few indicators of any other specific type of tool production. This suggests that Landmark Gap Quarry material was used primarily to produce expedient tools, whereas more formal tools were made of Long Tangle Lake Quarry material. Further, initial reduction of the Landmark Gap Quarry material may have taken place at the quarry itself, for complete raw material nodules do not appear to have been transported back to the site. The difference in how the Landmark Gap and Long Tangle Lake Quarry materials were used at XMH-35 provides an additional line of evidence for selective procurement of the Long Tangle Lake Quarry material, specifically for formal bifacial technologies. It is possible that the Long Tangle Lake Quarry material was procured selectively as nodules within an embedded procurement round and then used to produced bifaces and other tools at the site. Further, bifaces made of the Long Tangle Lake Quarry material may have been produced offsite in a procurement round and subsequently maintained and resharpened at the site. On the other hand, the Landmark Gap Quarry material may have been picked up in the embedded procurement round and used expediently for some subsistence purpose in the vicinity of the quarry. Alternatively, a nodule of this material was detached from the bedrock as an opportunistic resource and reduced to a desired package size to be transported back to XMH-35.

The Landmark Gap Trail Site shows a slightly different pattern in material use than XMH-35. The consistent pattern between the two sites is that there are no signs of primary nodule reduction of Landmark Gap Quarry material. This points to an aspect of Landmark Gap Quarry quarrying strategy that the material fractures better for early cortex removal, likely at the quarry itself. Different from XMH-35, the Landmark Gap Quarry material shows signs of bifacial thinning and the increased proportion of prepared platforms suggests more variety in planned tool production. There seems to be expedient tool production of this material as well. With regard to Long Tangle Lake Quarry material, bifacial sharpening was not the focus but every stage of nodule reduction and tool production was apparent. There is a stark contrast between biface production being the main use of the Long Tangle Lake Quarry material at

XMH-35, while this was not the focus of this material at the Landmark Gap Trail site. However, the Long Tangle Lake material still seemed to be preferred for tool production, such that the material was specifically introduced to the site for tool production purposes and is represented by all stages of reduction. The presence of bifacial thinning flakes and signs of expedient tool manufacture but no cortical pieces of the Landmark Gap Quarry material, suggest this material played more of an important role offsite in the subsistence round than the purpose of tool production at the site.

Whitmore Ridge C2 shows similar patterns of use between materials from Long Tangle Lake and Landmark Gap quarries. The Long Tangle Lake Quarry material seems to have been used more specifically for bifacial thinning, though both expedient and formal tools were produced from the nodules on site, due to the high presence of cortical flakes. There were fewer cortical flakes of the Landmark Gap Quarry material, however there appears to be complete nodule reduction at this site and both formal and expedient tools were produced. Due to the apparent preference for Landmark Gap Quarry material at this site, it is surprising not to see more specialization of technology on this material. Yet it is the only site where it seems like more complete nodules of Landmark Gap Quarry material were being introduced to the site, which is a line of evidence that confirms direct procurement over embedded procurement strategies of the other two Northern Archaic sites.

Finally, Whitmore Ridge C1 shows a lack of biface production on either material. Similar to Whitmore Ridge C2, Landmark Gap Quarry material may have been introduced to the site as more complete nodules and reduced entirely at the site, being used to produce a variety of tools, mainly formal tools. The Long Tangle Lake Quarry material seems to have been reduced similarly at the site but used more for expedient tools rather than formal tools. Another piece of evidence that would be helpful for this component would be microblade material type to see if a particular material was preferred for microblades. The information gained about the materials at Whitmore Ridge C1 does not offer much more evidence for the procurement strategy and site use, except that Landmark Gap Quarry material may have been preferred and directly procured for formal tool production, due to the presence of cortex of this material.

6.8 Procurement Strategies and Site Type in Context of Denali and Northern Archaic Land Use

As this discussion has highlighted, procurement strategies tend to be different based on site type more than distance to the source or change in time associated with the Denali and Northern

Archaic. The Northern Archaic components show that despite Whitmore Ridge C2 having an older radiocarbon date than the Landmark Gap Trail and XMH-35 components, eventually populations from the three sites may have been part of a local seasonal subsistence strategy, in which procurement of lithic materials was closely tied into each site's functions in a seasonal subsistence round. The Northern Archaic component (C2) at Whitmore Ridge has the most distinct pattern of raw material use and procurement of the Northern Archaic sites. Though the Landmark Gap Quarry material was likely selectively procured at Whitmore Ridge, treatment of the Landmark Gap Quarry material verses other local materials did not suggest that the material was selected and only used for a specific activity. Therefore, the site's location, relatively closer to the Landmark Gap Quarry for consistent direct procurement of material within the subsistence round, likely had greater bearing on how and why the material was obtained than what it was used for. Therefore, during the Northern Archaic occupation in the Tangle Lakes people appear to be well mapped on to the landscape and have a slightly more logistically mobile strategy, in which the procurement of lithic materials was adjusted based on the type and location of logistical site (Potter 2008b). Therefore, it may be inferred XMH-35 was a seasonal residence, due to the upland setting, and the Landmark Gap Trail site was likely a specialized logistical tool production and lookout site within the subsistence round of the same population as XMH-35. If the populations at Whitmore Ridge C2 did eventually overlap with the other two populations the specialized site type and activities (likely a seasonal caribou hunting camp) required a specialized material procurement strategy distinct from the other Northern Archaic sites two sites.

An alternative explanation for the difference between the Northern Archaic component at Whitmore Ridge and the other Northern Archaic sites in the study is: the possibility that occupants of Whitmore Ridge C2 were a part of an entirely different population from the occupants of the Northern Archaic residence XMH-35, and the Landmark Gap Trail site that practiced different mobility and subsistence strategies. This is postulated because the radiocarbon date range of the sample selected from Whitmore Ridge C2 was older and did not overlap with the dates of XMH-35 and the Landmark Gap Trail site; therefore, it is not possible to be sure that the occupation of Whitmore Ridge C2 overlapped with the other Northern Archaic components. It is possible that the populations were both logistically and residentially mobile but people that occupied XMH-35 and the Landmark Gap Trail site were logistically mobile, while other groups of people who were more residentially mobile occupied Whitmore Ridge, possibly a reminiscent strategy of previous Denali occupants at the site.

The difference between Whitmore Ridge C1 and C2 can be compared to understand the influence of culture and technological strategy on procurement and land-use shifts between the Denali and the Northern Archaic populations. Only these two Whitmore Ridge components are directly compared between the Denali and Northern Archaic due to the small well-dated component sample size in the Tangle Lakes Region associated with the Denali complex. Whitmore Ridge is one of the only sites in the Tangle Lakes that appears to have been occupied through time as it was utilized during the Denali occupation and then after a technological shift to the Northern Archaic. However, based on material and technological comparison of the two components, despite a change in technology from a microblade dominated industry to a bifacial dominated industry, it does not appear that the material procurement strategy at this site changed. This conclusion suggests that the site type and activities dictated the procurement of materials at the site, and the activities fit into a subsistence strategy that utilized direct procurement of Landmark Gap Quarry material through time. It is possible during the Denali occupation at Whitmore Ridge C1 there was less landscape knowledge, therefore the closest reliable raw material resource was utilized (Landmark Gap Quarry). However, there is also some Long Tangle Lake Quarry material which suggests people knew about the location of this quarry and chose to use more Landmark Gap Quarry material. The location, continuous occupation, and heavy procurement of the Landmark Gap Quarry material suggests that the Denali component at Whitmore Ridge (C1) was a specialized seasonal occupation where hunting activities required direct procurement of material or a more residentially mobile strategy limited inhabitant's contact with certain lithic resources.

The technological organizational strategies in this study can be understood in the context of broader behavioral patterns that have been attributed to the Denali and the Northern Archaic periods, as well as to Ahtna ethnography. Though there is not faunal data to support high resolution seasonality in site use, some general aspects of how procurement and landscape use at the sites fit into seasonal subsistence can be inferred based on site type, activities, and general ethnographic comparison. In a general sense, XMH-35 may have been a residence for the Spring through Fall because if its upland setting and was likely occupied continuously during these months (Potter 2008b, 2008c). Alternatively, Whitmore Ridge may have been occupied for a shorter time during these months associated with upland game migrations consistent with the Ahtna ethnographic subsistence strategy (Reckord 1983). It is possible that the Landmark Gap Trail site was not continuously occupied like the residence XMH-35, but could have been used repeatedly during the seasonal occupation of Tangle Lakes. The Ahtna oriented their calendar and subsistence around a two-part year: summer, beginning with breakup in late April; and winter, beginning in November. Subsistence related mobility included summer salmon camps, to summer upland meat camps, to river drainages in the fall for trapping and hunting, then families gathered in winter houses near the summer fish camps (de Laguna and McClellan 1981). The description of Ahtna winter residences matches well with the location and features at XMH-35, and contrasts distinctly with Whitmore Ridge. Ahtna winter houses were rectangular with an excavated floor and walls built with vertical posts. Cooking took place around a central fireplace. There were also smaller moss houses built in the woods and out of the wind for trapping and hunting (de Leguna and McClellan 1981). Ethnographic accounts of Ahtna subsistence and occupations describe numerous village sites around Paxson Lake, notably one large winter-village, where the inhabitants took advantage of the resources in the lake and drove caribou into the lake to hunt (Reckord 1983). It is not possible to determine with certainty whether XMH-35 was a winter residence as suggested by the ethnographic evidence, or an upland Spring through Fall residence based on archaeological patterns in the area. I would argue for the latter based on lack of confidence in valid direct ethnographic comparisons to prehistoric archaeology in the region. Ahtna caribou fences have also been documented within the Tangle Lakes region. If ethnohistoric occupation of the region has any similarity to the use of the Tangle Lakes landscape during the Northern Archaic occupation, then this provides another line of evidence for seasonal procurement strategies.

The interpretation of the Denali component at Whitmore Ridge C1 is consistent with models that evaluate the Denali complex variability between the Late Pleistocene and Early Holocene based on subsistence economy and technological organization in different physiographic regions. The seasonal model accounting for technological variation during the Denali Complex suggests there was seasonal variation in hunting strategies based on the procurement of large game, though variability in diet breadth is increased when including seasonal camps in faunal assemblage analysis (Potter 2008a, 2011). There is a pattern during the Late Pleistocene – Early Holocene suggesting statistically significant association between microblade technology, lowland sites, and bison and moose habitats while there is also a significant relationship between bifacial technology, upland sites, and caribou and sheep habitat (Potter 2011). Therefore, in general Denali populations were to be highly residentially mobile, while also likely practicing some levels of logistical mobility as well (Potter 2008b). This mobility strategy may have allowed Denali populations to maintain a wide diet breadth by exploiting resources in the immediate area during the season of the residence (Potter 2008b, a). All of Tangle Lakes falls within the upland physiographic region including all of the sites in this study. Interestingly, the analysis of the sample Whitmore Ridge C1 showed a low proportion of bifacial thinning technology, though it was certainly present. Documentation of the whole sample suggests that bifacial production was present in the component, however there was a large proportion of microblade technology. Despite being an upland region, both moose and caribou are available, in addition to waterfowl, fish, and vegetation such as berries (Gallant et al. 1995). Therefore, it makes sense for Whitmore Ridge C1 to have some bifacial hunting tools, as well as microblade technology to be able to obtain the variety of resources that the Tangle Lakes presents. If Whitmore Ridge C1 was a summer season subsistence and hunting habitation then it is expected that tool production should be the focus for a variety of resources that could be obtained there in the summer. The lookout location may provide a good vantage point for any large game, and the consistent occupation of the location could indicate a prime location for hunting along a caribou migration route.

Though older technological forms associated with the Denali Complex such as microblades and wedged cores continued into the Northern Archaic technological strategies in subarctic Alaska, there was a shift to new technological forms with the Northern Archaic tradition. The Northern Archaic Tradition is recognized by the introduction of lithic notched biface forms, though microblade technology was still present to a lesser degree. The change in in technology between Denali and Northern Archaic populations could be due to diffusion, assimilation, replacement. Specific differences in subsistence economy and mobility strategies between Denali and Northern Archaic populations has been identified by: (1) changes in resource scheduling, (2) increased diet breadth, (3) change from more of a focus on residential mobility to a slight increase in logistical mobility and storage, (4) possible changes in availability of large game, such as bison, (5) increased use of upland regions by Northern Archaic populations (Potter 2008b, a). Some other archaeologists have argued that microblade technology is a material conservation technique when occupying lithic resource poor areas (Clark 2001; Coutouly 2012; Flenniken 1987). This hypothesis is not supported by this study, as microblade technology exists at Whitmore Ridge in an area of local lithic material abundance (see discussion in Potter 2008b).

The Northern Archaic residential site XMH-35 is located the farthest from the mountains though still within the upland physiographic region, but it is consistent with the idea that Northern Archaic residences were located in lowland regions; however, the selective procurement of Long Tangle Lake

Quarry material for bifacial technology, which is more attractive and farther away from the Landmark Gap Quarry indicates that inhabitants did not produce bifacial technology because of lack of access to high-quality material, but rather sought out high quality material in the subsistence round.

Alternatively, although it was clear that Denali Complex inhabitants of Whitmore Ridge C1 had knowledge of other higher quality toolstone sources, the inhabitants utilized the immediately available lower quality Landmark Gap Quarry source. The preference for Landmark Gap Quarry material did not change over time. Therefore, this research suggests though there may have been different site and mobility organization in the Tangle Lakes region, but technological organization including lithic resource procurement was largely driven by site type and the site's function within a seasonal subsistence round.

Chapter 7 Conclusion

7.1 Conclusion

This research answers questions about prehistoric raw material procurement, mobility, and landscape use between the Early and Mid-Holocene in the Tangle Lakes region, Alaska. Data used to answer specific questions about procurement and mobility patterns include (1) chemically sourced artifacts from two Tangle Lakes quarries, (2) compositional and physical information about the quarry sources, (3) lithic attributes from assemblage samples of three different sites and four components in the Tangle Lakes, (4) existing information about site type, (5) ethnographic information, and (6) broad patterns associated with human behavior during these time periods. This research demonstrated that the Landmark Gap and Long Tangle Lake Quarry contributed significantly to lithic assemblages in this study resulting in the ability to identify high resolution lithic procurement strategies associated with these quarries in the Tangle Lakes region. 'Best-practice' methods of chemically sourcing these quarries developed through this research provided the quantitative base for making assertions about raw material distributions from these quarries for identification of procurement strategies. The procurement of materials in the study sites appears largely to be conditioned by site type and activities associated with each site's function in the overall mobility strategy. Change between Denali and Northern Archaic occupation does not seem to condition procurement as clearly as site type. This knowledge about high resolution procurement strategies, mobility, and land use of Tangle Lakes populations allows the behavioral patterns from this region to be incorporated into the overall understanding of Denali and Northern Archaic behavioral patterns in sub-arctic. These conclusions were drawn based on the answers to the following questions:

(1) What types of activities were performed at each site component?

XMH-35 is a Northern Archaic residential site where all stages of lithic reduction and tool production took place, with an emphasis on late-stage reduction and bifacial tool maintenance. The Landmark Gap Trail site is a Northern Archaic tool production site and game lookout, with all stages of reduction present but greater focus on early-stage nodule reduction though bifacial maintenance and tool production was apparent. Whitmore Ridge C2 likely represents a seasonal subsistence occupation that produced a variety of tools and performing biface maintenance with every stage of reduction and tool production taking place at the site. Whitmore Ridge C1 is likely a summer subsistence tool production site with all stages of reduction and production present, including a large amount of early stage decortication, a small amount of bifacial production and maintenance.

(2) Is there differential treatment of raw materials in each component?

The Landmark Gap and Long Tangle Lake Quarry materials are treated differently in each component. The materials seem to be used for different purposes at each site. While, Long Tangle Lake Quarry material seems to be selectively procured at XMH-35, Landmark Gap Quarry material was selectively procured at the Landmark Gap Trail site, and Whitmore Ridge in both components (C1 and C2). Initial nodule reduction of Landmark Gap Quarry material was not present at the Landmark Gap Trail site or XMH-35, but initial nodule reduction of this material was present in the Whitmore Ridge components. At XMH-35 Long Tangle Lake material was bifacially thinned while Landmark Gap Quarry material was not. Alternatively, at the Landmark Gap Trail site, a larger proportion of Landmark Gap Quarry material was bifacially thinned than the Long Tangle Lake Quarry material. At Whitmore Ridge, it appears that both expedient and formal tools were made on both materials but there was a greater proportion of Landmark Gap Quarry material. The differences in how the materials were treated within the Northern Archaic components appears to be largely associated with the different activities that took place at the different site types. Further, differences are likely due to material entering the sites at different times in the subsistence round. Differences between the Denali and Northern Archaic component at Whitmore Ridge suggest that variation between components in how the materials were used could be a result of slightly differential reliance on certain technological forms through time or increased levels of logistical mobility in an already residentially mobile system, changing access to certain materials.

(3) How does the treatment of the Tangle Lakes Quarry material and the Landmark Gap Quarry material compare to the estimated local and non-local materials in each component?

The Landmark Gap Trail site and Whitmore Ridge C1 lack non-local materials; however, in the sites that had non-local materials, patterns of how Long Tangle Lake material was used are similar to that of the non-local materials in these sites. This pattern could be indicative of a number of behaviors such as: When non-local materials ran out the tools were replaced by the highest quality local material (Long Tangle Lake Quarry material) rather than more inferior Landmark Gap Quarry material (MacDonald 2008); the Long Tangle Lake material being valued equally with non-local raw material because of quality or difficulty in acquisition (Carr 1994; MacDonald 2008); or acquisition of non-local material could have been incorporated into a portion of the mobility strategy that allowed people to come into contact with the Long Tangle Lake Quarry material (Seeman 1994; Stothers 1996). Local materials tracked similarly to the local materials, which suggests that some of the estimated local materials could potentially be chemically sourced to the Landmark Gap Quarry or the Landmark Gap Quarry materials were used similarly to any other material nodule that was acquired locally.

(4) What procurement strategies can be identified for each site component?

Multiple lines of evidence predicted the procurement strategies within each site component consistently. It is suggested from this research that an embedded procurement strategy associated with a logistical mobility pattern was used to selectively acquire Long Tangle Lake Quarry material at XMH-35. An embedded procurement strategy within a logistical mobility pattern is suggested material acquisition at Landmark Gap Trail site. The Landmark Gap Quarry material seemed to be preferred at the Landmark Gap Trail site but almost equal amounts of Long Tangle Lake material suggests an embedded procurement strategy for lowering the costs associated with acquiring this material. Further, the Long Tangle Lake Quarry material could have been acquired first in the procurement system at the Landmark Gap Trail site and the Landmark Gap Quarry material could have been acquired right before returning to the site, which may be why there is slightly less Long Tangle Lake material at the site. Direct procurement and preference of Landmark Gap Quarry material is suggested for both components at Whitmore Ridge, where this procurement strategy seems to be tied closely with site type and associated activities through time. It is possible, if the site was used as a hunting camp for caribou direct procurement was needed to minimize risk of not having the material for tools when encountering game, or minimize the time for acquiring the material and potentially missing a chance to hunt game (Bousman 2005).

(5) Are mobility and procurement strategies different through time?

It does not appear that procurement strategy shifted through time based on comparison of Whitmore Ridge C1 and C2. This is a strong indication that site type and related activities have a greater bearing on material procurement than changes in populations with slightly different subsistence economies and mobility strategies. Potential changes in the degree of residential and logistical mobility through time, such as slight increases in logistical mobility during the Northern Archaic Tradition, could have had a potential effect in how non-local materials were incorporated into the Whitmore Ridge site because non-local material is not present in the Denali component, but present in the Northern Archaic component. However, overall the suggested procurement strategy and material preference does not change through time.

(6) Does site functional type consistently influence procurement and mobility?

Site type is likely the main factor contributing to material selection and procurement. This is demonstrated by consistency in material procurement and selection between the Denali and Northern Archaic components. Consistency is also demonstrated by some differences in material procurement, preference, and treatment between the three Northern Archaic components, each with a different site type. This study offered a significant opportunity to evaluate site type as a conditioning factor material preference and procurement because most prehistoric studies are limited to samples from one site or several sites that have the same site type. Therefore, the ability to recognize site type as a conditioning factor of material procurement and technological organization is significant for archaeologists when posing questions and designing models where site type needs to be controlled. Further, in the broader context of Denali and Northern Archaic behavioral patterns though these populations may have had different subsistence economies and varying levels of mobility, the strategies that surround the fundamental need to lithic material in technological organization does not seem to change.

(7) How do the technological strategies employed at these sites fit into the broader context of Early through Mid-Holocene human behavior in central Alaska?

The site components appear consistent with the with current models of mobility and subsistence procurement strategies between the Early and Mid-Holocene in interior and central Alaska. However, the results do not fit the hypothesis that microblade technology is a material conservation technique in times or locations of limited material availability (Clark 2001; Coutouly 2012; Flenniken 1987). Higher-quality Long Tangle Lake Quarry and non-local materials were incorporated into Northern Archaic biface production, while nearby poorer-quality Landmark Gap Quarry material was utilized to a greater extent at Whitmore Ridge C1 for all stages of lithic production except for initial nodule reduction and formal tool production.

The scale of this analysis, such that local procurement strategies could be teased out of the archaeological record within the Tangle Lakes region would not have been possible without the ability to chemically source two prominent lithic quarries. Visual sourcing of lithics to either of these quarries is unreliable and could result in false raw material patterning in lithic assemblages. This approach assigned artifacts to the quarries quantitatively and was conservative in that only the artifacts that were appropriate for chemical analysis were used. Even with a small sample size that is representative of the dated assemblage sample it is possible to see clear archaeological patterns.

This research has definitively established that both quarries were utilized from the earliest occupation of Tangle Lakes in the early Holocene through the Mid-Holocene. The use of these quarries may represent thousands of years of local landscape learning allowing for reliable lithic resources through situations of risk with changing subsistence resource pressures. Because lithic resources are constant until depleted, but subsistence resources may change through time, people could change their mobility strategies to adapt for faunal and vegetation resource change while maintaining access to the same lithic resources. This is potentially the reason for seeing consistency in material proportions and uses through time at the Whitmore Ridge site.

7.2 Significance

Previous archaeological research within Alaska and most other archaeological research in general has not successfully chemically defined non-igneous toolstone sources and statistically attributed artifacts to the sources. Kristensen et al. (2016) successfully defined silicified sandstone deposits using portable x-ray fluorescence spectrometry and assigning artifacts using bivariate plots. However, archaeologists have not defined metamorphic material and made artifact assignments with quantitative chemical and multivariate statistical rigor. Therefore, this successful chemical sourcing study should be considered a 'best practice' method for defining non-igneous material and assigning artifacts. Furthermore, analysis including the compositionally sourced artifacts provided a high resolution picture of local procurement and mobility strategies within the Tangle Lakes, that fit into the broad understanding of settlement and subsistent strategies between Denali and Northern Archaic populations. Site type has been demonstrated as a main conditioning factor for material procurement rather than changes in Denali and Northern Archaic Traditions through time, which is significant for understanding that despite broad patterned changes in mobility strategies and subsistence economies the base of technological organization (material procurement) may not change.

7.3 Future Directions

The dataset and numerous lines of evidence were able to shed light on patterns of local lithic resource procurement in the Tangle Lakes. However, the dataset was limited in size due to time and limited amount of securely dated large lithic assemblages. Future work should attempt to chemically analyze all lithic materials of the appropriate analytical size and shape from the complete assemblages from each site from all time periods represented in the Tangle Lakes. Particular focus should be placed on chemically analyzing the entirety of each assemblage directly associated with a date rather than a sample. Further, it would be beneficial to incorporate additional Denali Complex assemblages into this analysis, such as the Phipps site. However, one problem with adding additional components from sites within the Tangle Lakes region is that many of them do not have reliable dates. Future work should also extend to assemblages outside of the Tangle Lakes to chemically analyze other unidentified non-igneous materials in Alaska. An analytical routine may be developed allowing other archaeologists in Alaska to compositionally analyze non-igneous artifacts that they suspect might be coming from the Tangle Lakes sources. These 'best-practice' methods of compositionally identifying non-igneous quarry material and sourcing similar non-igneous artifacts may be applied to study areas where the location of primary source material is known.

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Appendices

Appendix A

<u>Site Stratigraphy and Excavation Maps of the Landmark Gap Trail Site</u>

The Landmark Gap Trail Site was excavated by Mobley and Morris in 1980 and again in 1992 by Gillispie. The sample was taken from Feature 1 excavated and documented by Mobley and Morris 1980 as lithics in Feature 1 are directly associated with a radiocarbon date. Site documentation, stratigraphic profiles and descriptions, excavation plans, and drawing of Feature 1 were produced from the Mobley and Morris 1980 excavation.

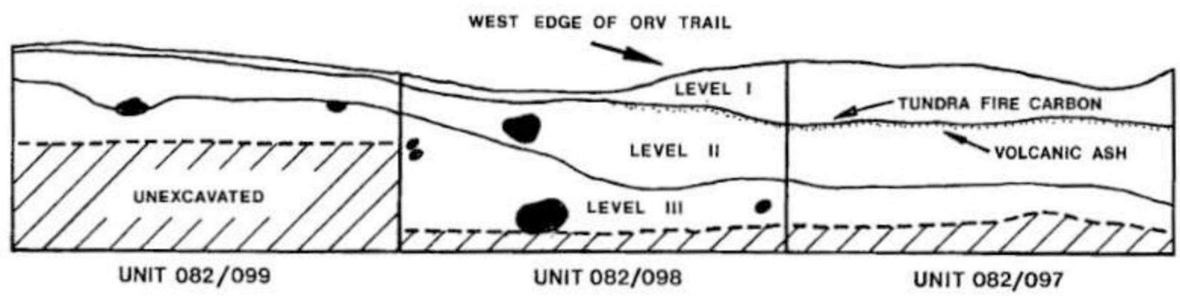

Figure A.1 Typical stratigraphic profile at the Landmark Gap Trail site (Mobley 1982).

Table A.1 Stratigraphic Descriptions at the Landmark Gap Trail site (Mobley 1982).

VEGETATION	Irregular mat of alpine tundra shrubs and mosses. Maximum thickness 20-30 cm.
LEVEL I	Loose dark brown silty loam formed from loess and decomposed organic material. Thickness averaged 10 cm or less.
TUNDRA FIRE CARBON STREAK	Thin lamina of carbonaceous soil. Structure consisted of small (1mm dia.) cylinders probably representing small stems and roots.
VOLCANIC ASH	Discontinuous layer of volcanic ash, up to 2 cm thick. Grades into the albic horizon of Level II
LEVEL II	Sequence of compacted grayish brown and dark reddish loam varying between 15-30 cm thick. Top few cm leached to lighter color than parent soil; second albic horizon (discerned only in Unit 089/097) found midway in stratum.
LEVEL III	Mottled dark grayish brown and dark yellow brown gravelly loam (glacial till) containing gravel, cobbles, and boulders greater than several kg in weight.

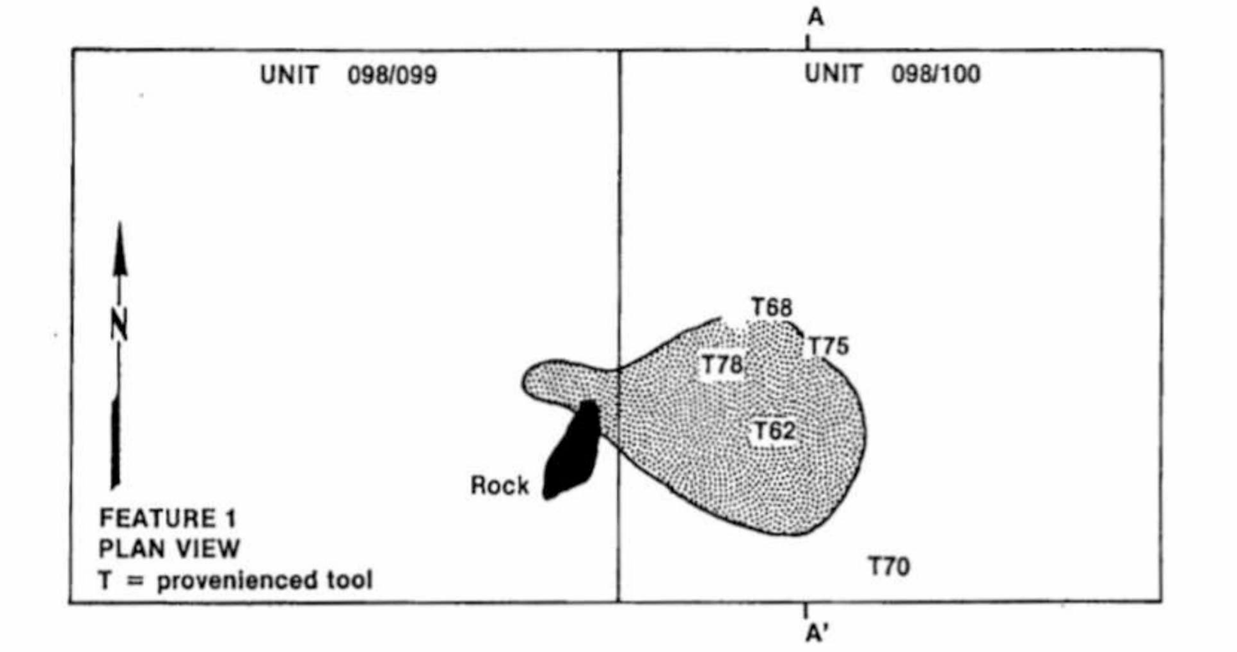

Figure A.2 Feature 1 at the Landmark Gap Trail site plan view (Mobley 1982).

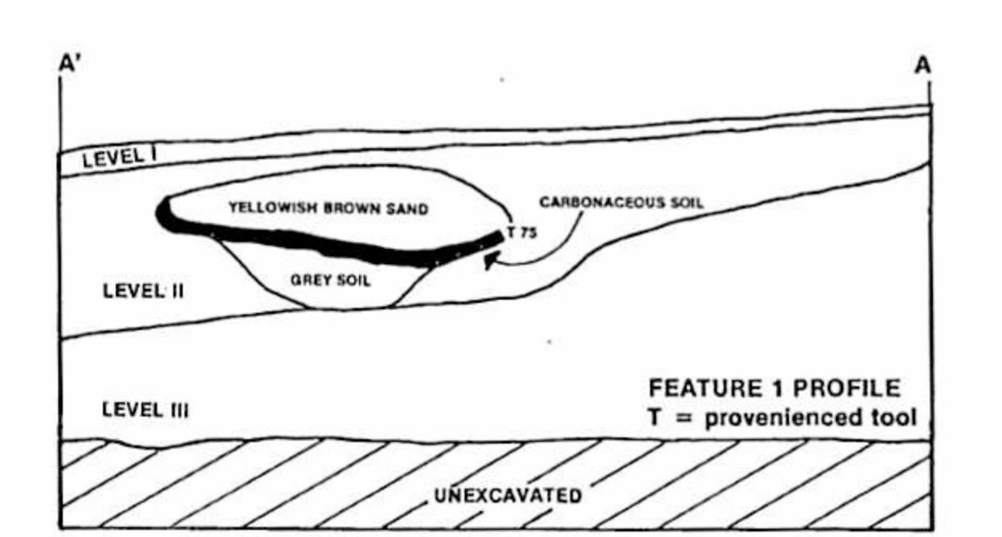

Figure A.3 Profile of Feature 1 at the Landmark Gap Trail site (Mobley 1982).

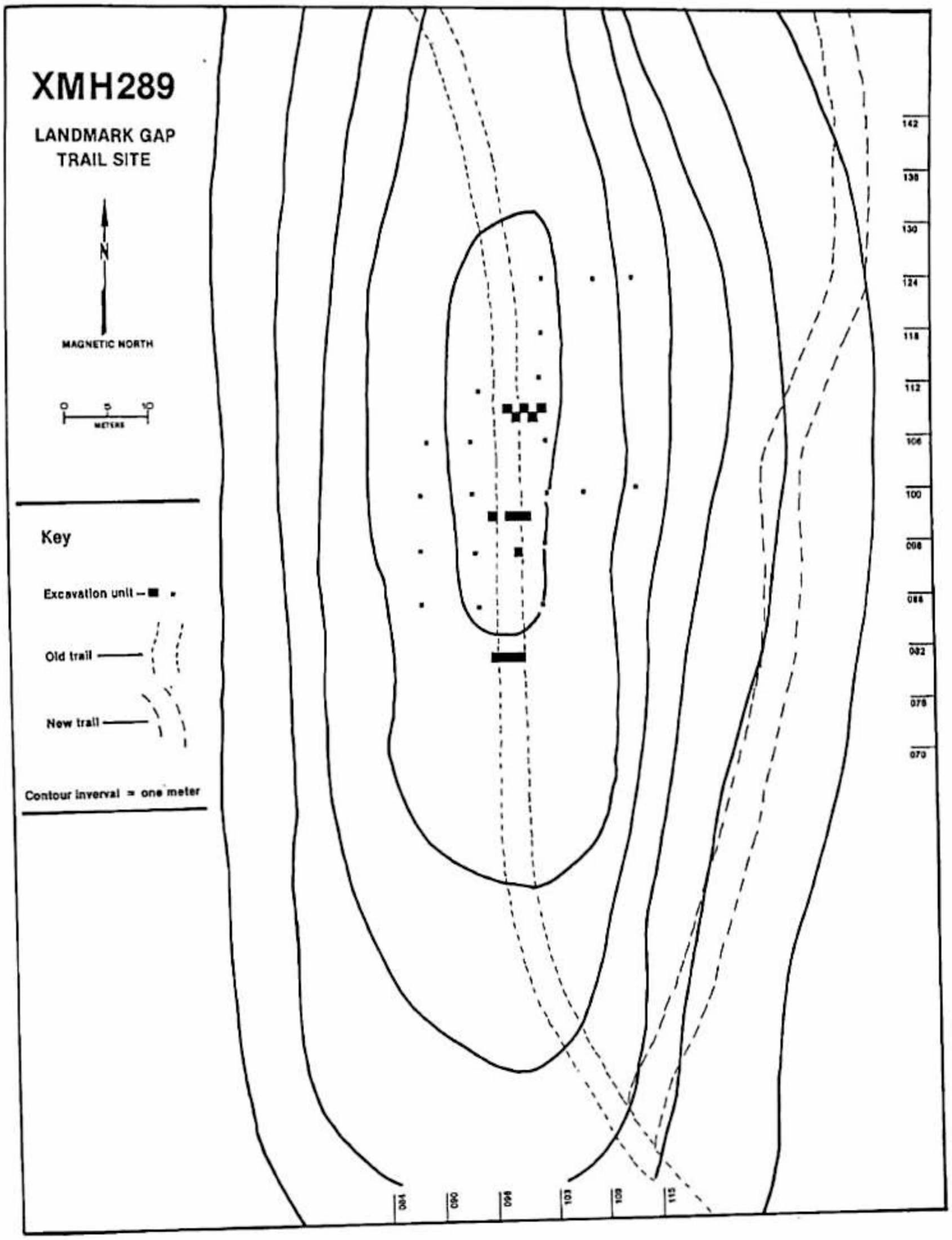

Figure A.4 Landmark Gap Trail site excavation plan view (Mobley 1982).

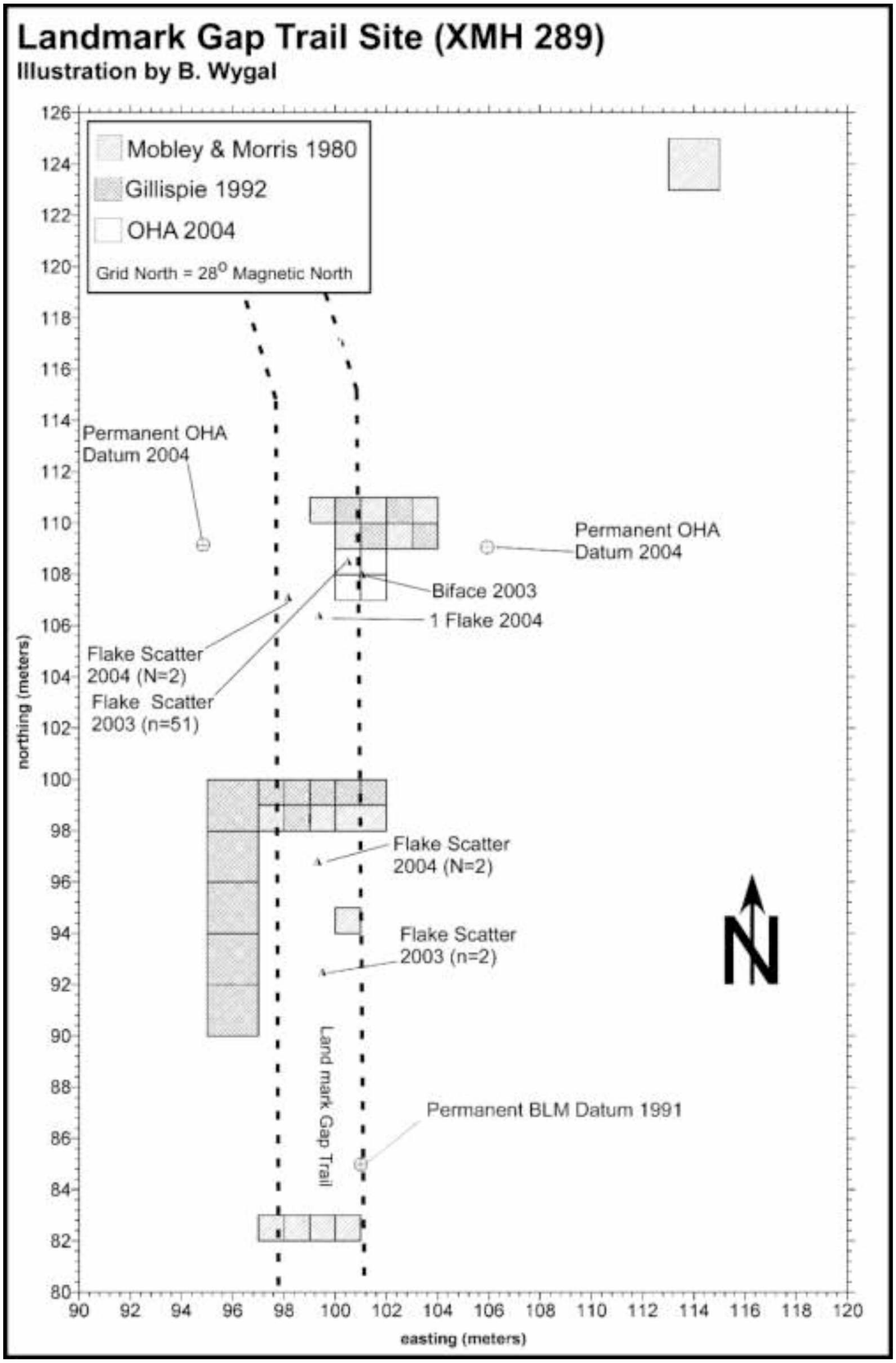

Figure A.5 Landmark Gap Trail site updated excavation plan view, provided by Tom Gillispie, personal communication, 2018.

Site Stratigraphic Dates and Excavation Maps of Whitmore Ridge

The Whitmore Ridge site was excavated in 1973 by G. Dixon.

Table A.2 Soil Horizons and Dates at Whitmore Ridge (West et al 1996).

Buried A Soil Horizon (Ab)

5480±300 (UGa-530)

3800±180 (Beta-64575)

5080±130 (I-4231)

Buried B Soil Horizon (Bb)

9890±70 (Beta-62222; CAMS-6406)

9600±140 (Beta-64578; CAMS-8300)

9830±60 (Beta-70240; CAMS-11255)

10,270±70 (Beta-77286; CAMS-16834)

Mt. Hayes 72 (Whitmore Ridge)
Radiocarbon dates
(F. West, B. Robinson)

Lower Bb

10,630±60 (Beta-77285; CAMS-16833)

(ca. 2 cm below flake concentration that produced Beta–77286)

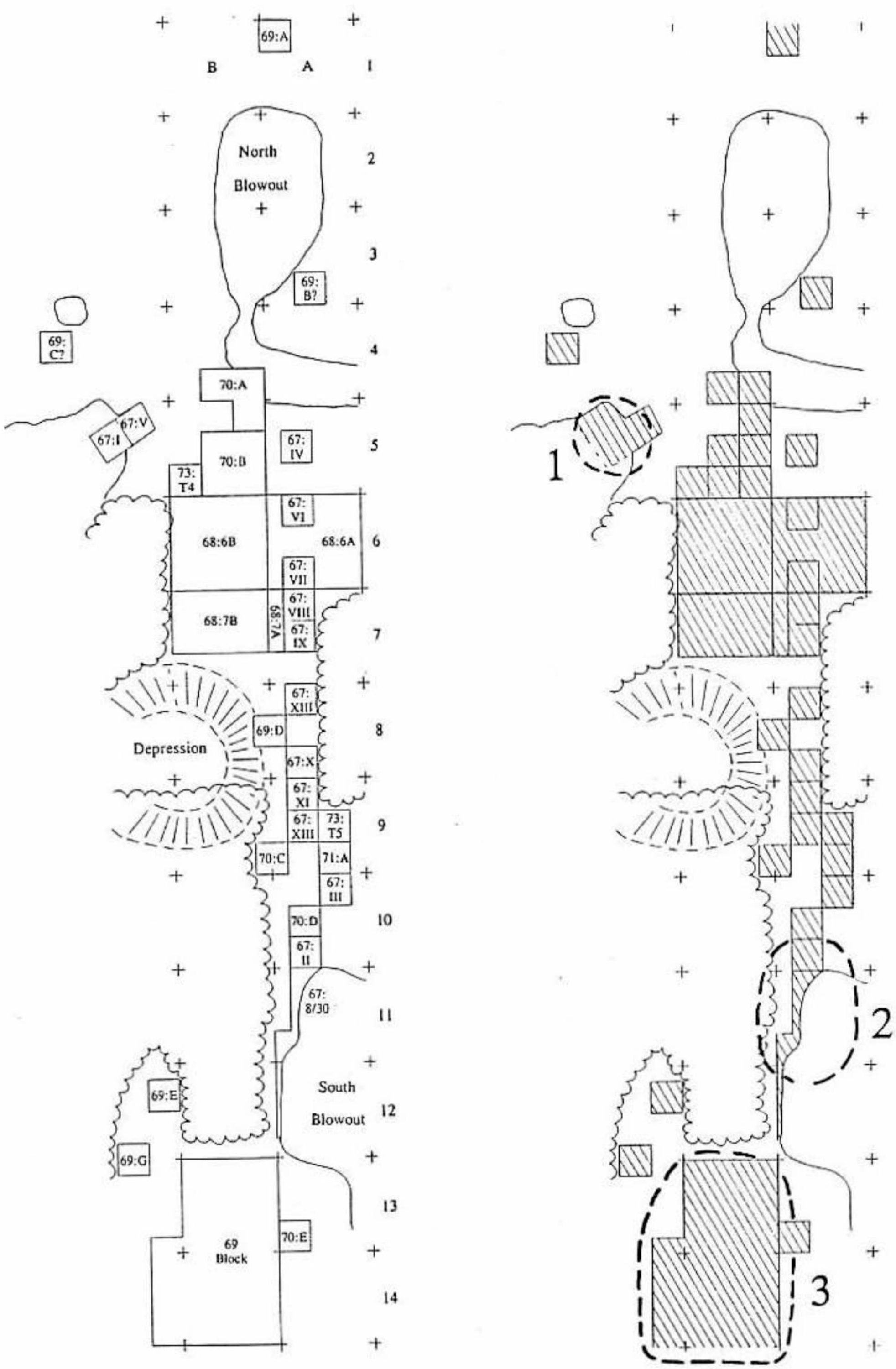

Figure A.6 Whitmore Ridge Excavation Plan View (Dixon 1973).

Site Stratigraphy and Excavation Maps of XMH-35

XMH-35 was excavated in 1964, 1967, 1968, and 1970 – 1972 by a combination of personnel including West, Reger, C. Flint, E. Peterson, G. Dixon, J. Hamilton, B. Hamilton, M. MacDonald. The figures were produced by B. Robinson in his 2002 report.

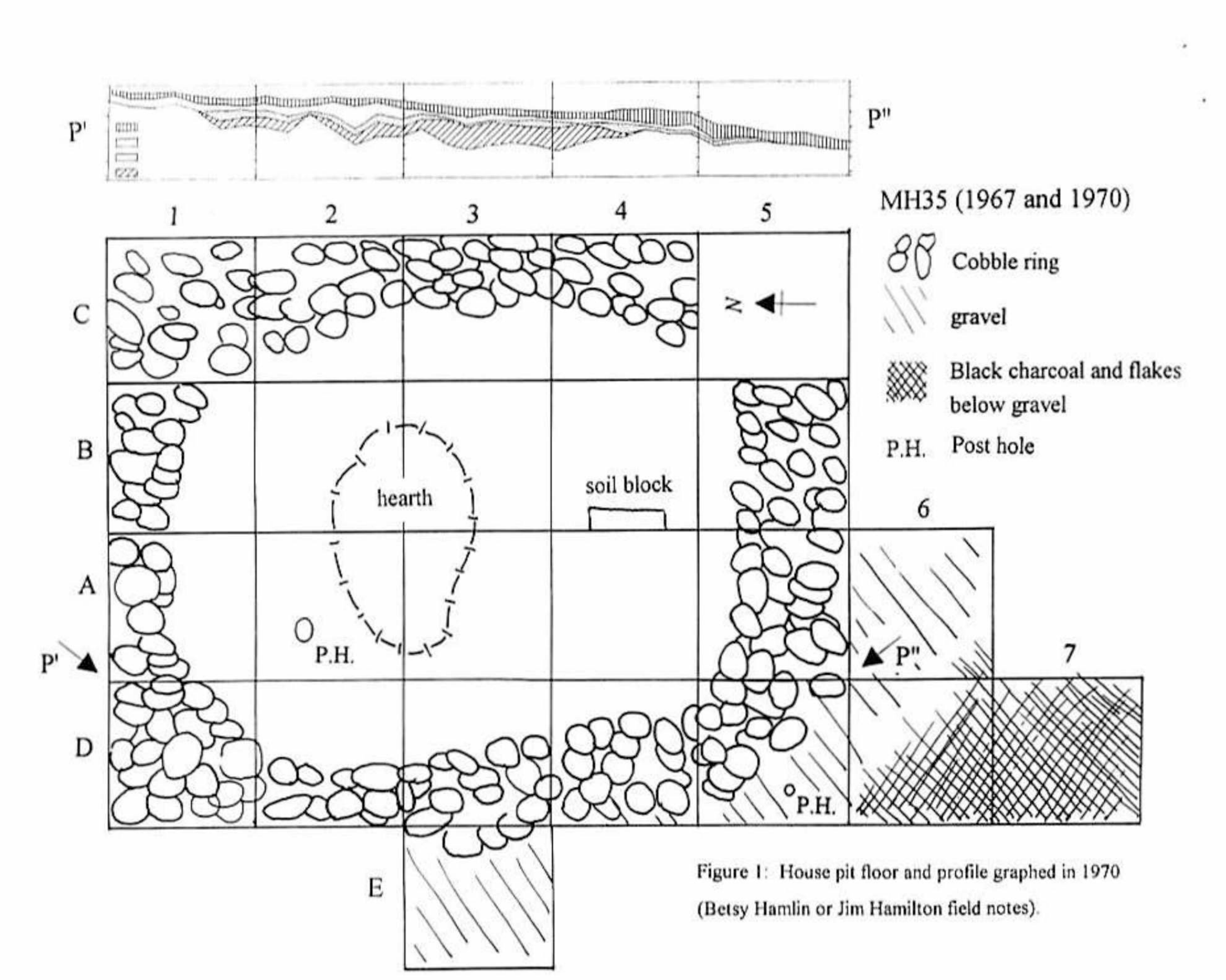

Figure A.7 XMH-35 excavation plan view (Robinson 2002).

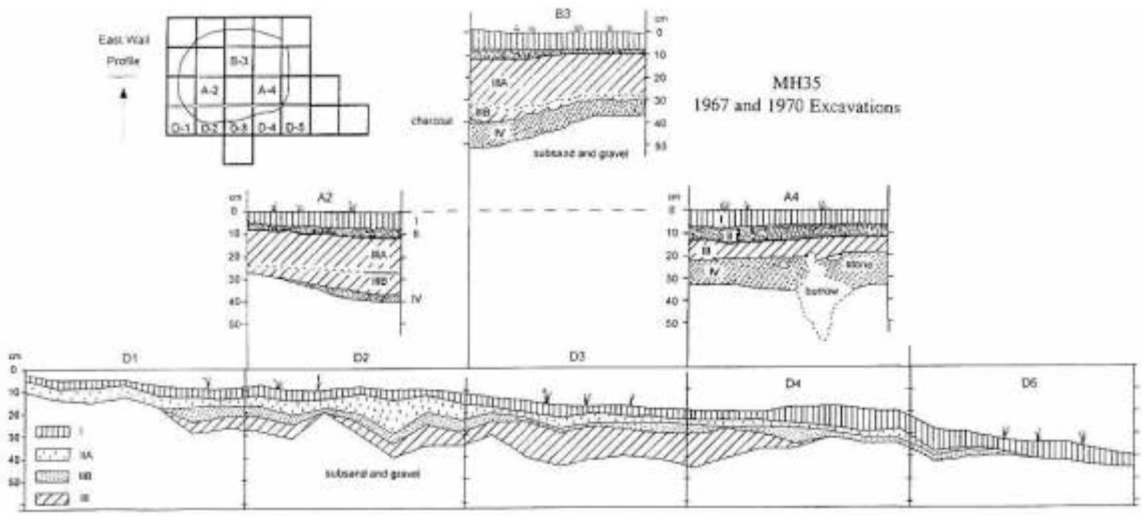

Figure 2: Stratigraphic profiles from 1967 (A2, B3 and A4) and 1970 (D1-D5) showing interior and edge of house pit, respectively. Strata are correlated between the two years with descriptions in Figure 3.

Figure A.8 XMH-35 stratigraphic p(Robinson 2002).

Artifact Levels	Cultural Zones	Approx-imate Depth	Strati-graphic Zone	Units Present
1	Upper soil	1-10	I-II	All
2	Mixed Artifact Levels 1 and 3	10-20	II-III	All
3	House fill, red and basal deposits	20-45	III	All
4	House fill, lower gray (specified)	20-45	IV	1967

Strati-graphic Zone	Profile Descriptions By Unit	East Wall Profile	Year
I	Moss roots level	All	both
II	Upper black, organic (dark)	A2, B3, A4	1967
IIA	Sandy loam, tan	D1-D5	1970
IIB	Gray podzol	D1-D5	1970
III	Red fill and red gravel at base	D1-D5	1970
IIIA	Reddish brown or brownish	A4, B3, B4	1967
IIIB	Yellowish or buff zone, diffuse upper contact	B3, B4	1967
IV	Gray, gray-black midden, with charcoal	A4, B3, B4	1967
Subsoil	Sterile sands and sand with gravel		

Figure A.9 XMH-35 stratigraphy and cultural zones (Robinson 2002).

Appendix B

Random Sample Sorter

A random sample sorter was designed to randomly select artifacts that were housed at the University of Alaska Museum of the North in "flake lot bags." Flake lot bags refer to bags filled with flakes of various sizes from the same location. The random sample sorter ensured that there was not a bias towards flakes of certain sizes, shapes, or material type.

Figure B.1 Random sample sorter.

Table B.1 Measurements of the random sample sorter.

Input (widest) diameter	19.4 cm
Output diameter	9 cm
Length of each cross section/chamber	4.5 cm

Appendix C

Regression Plots for Comparing Accuracy of Bruker ED-pXRF

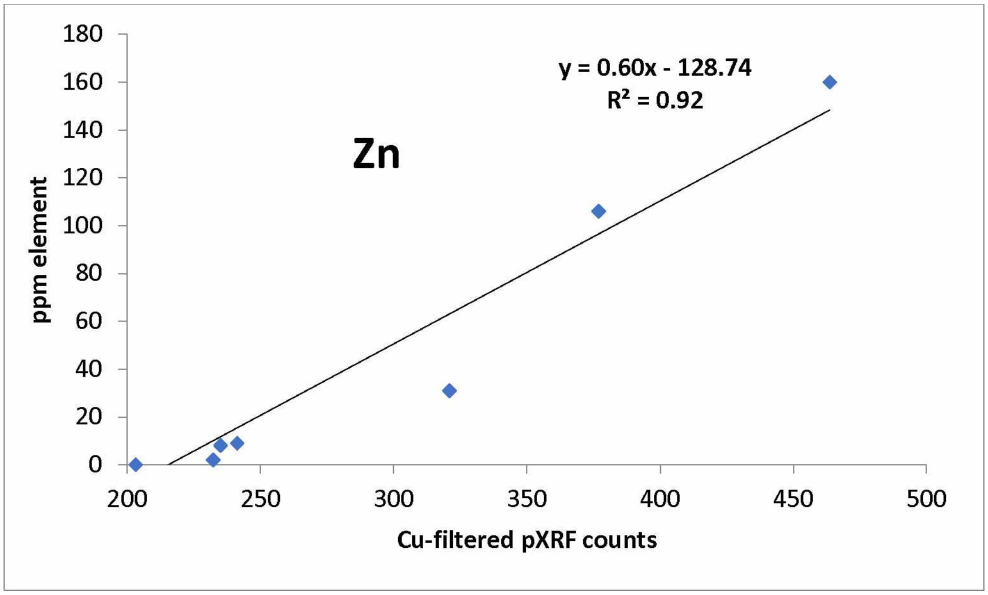

Figure C.1 Regression comparison of Zn raw counts collected on the Bruker verses actual values of homogenous standards.

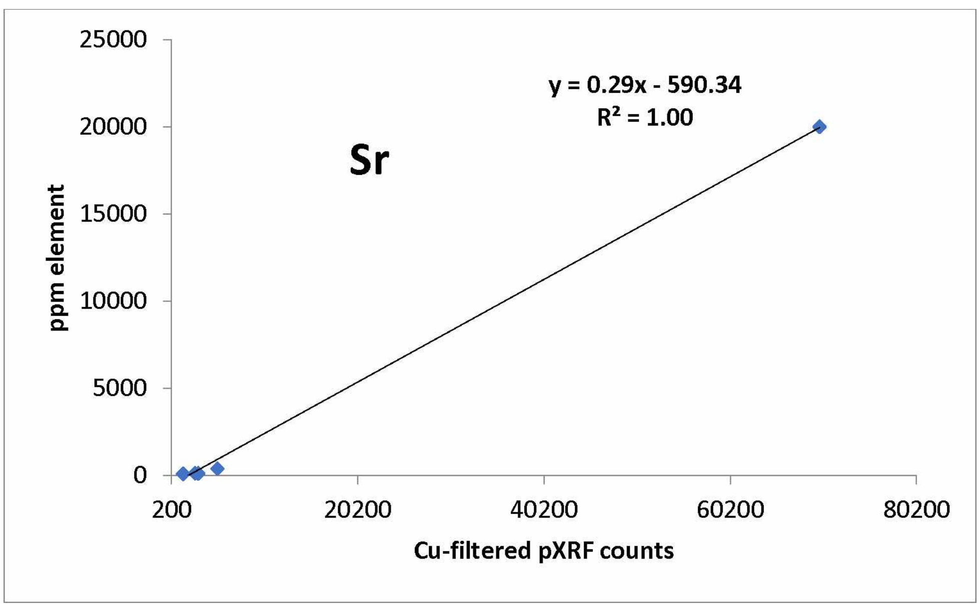

Figure C.2 Regression comparison of Sr raw counts collected on the Bruker verses actual values of homogenous standards.

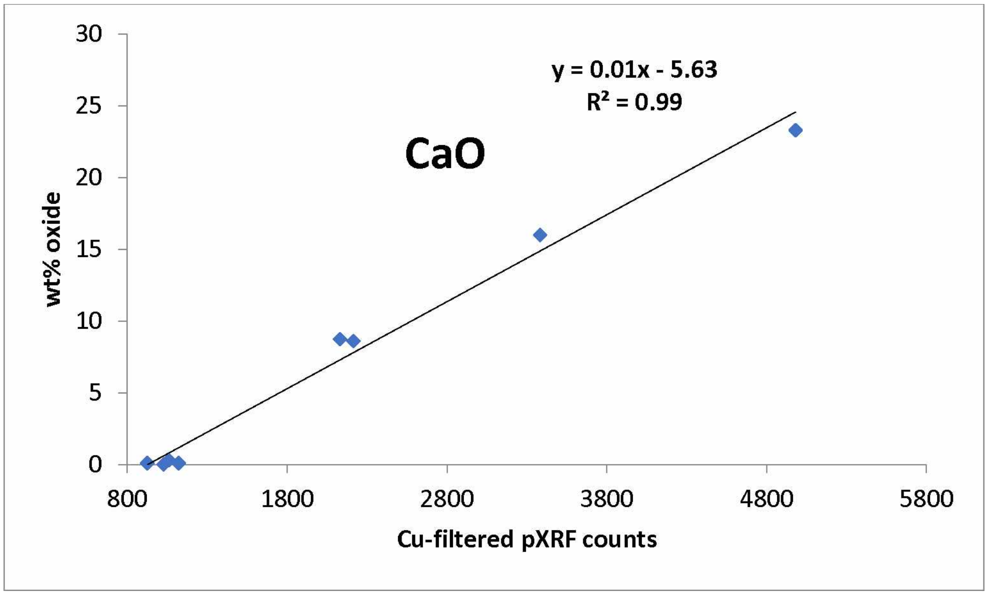

Figure C.3 Regression comparison of CaO raw counts collected on the Bruker verses actual values of homogenous standards.

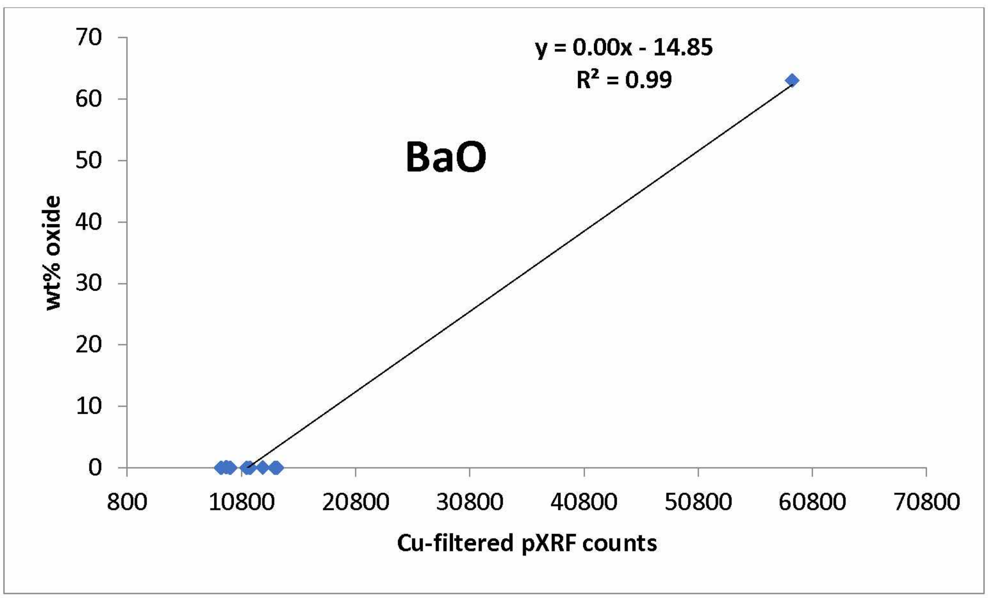

Figure C.4 Regression comparison of BaO raw counts collected on the Bruker verses actual values of homogenous standards.

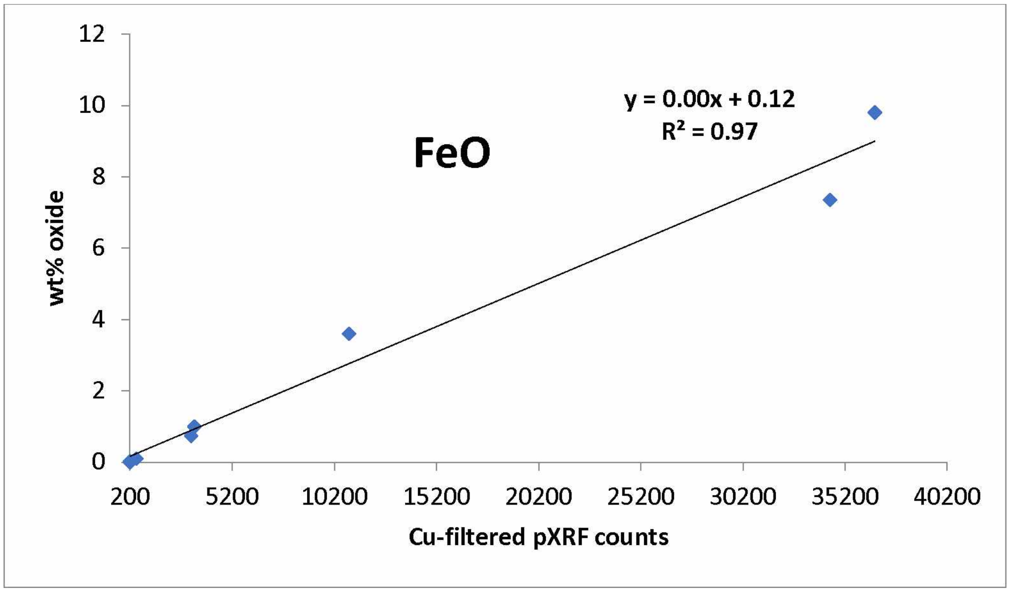

Figure C.5 Regression comparison of FeO raw counts collected on the Bruker verses actual values of homogenous standards.

Regression Plots for Comparing Accuracy of Niton

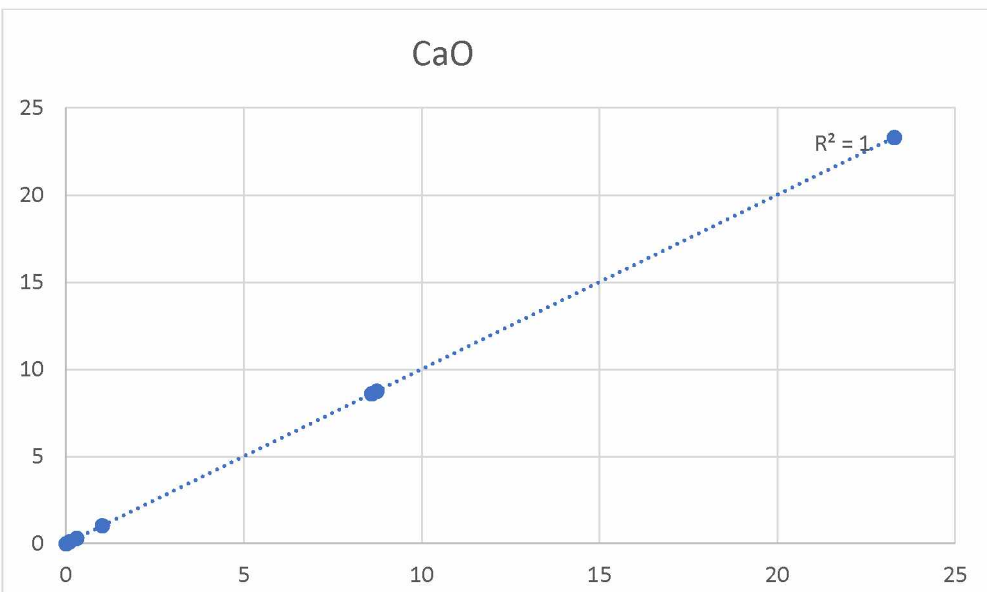

Figure C.6 Regression comparison of CaO weight percent concentrations collected on the Niton verses actual values of homogenous standards.

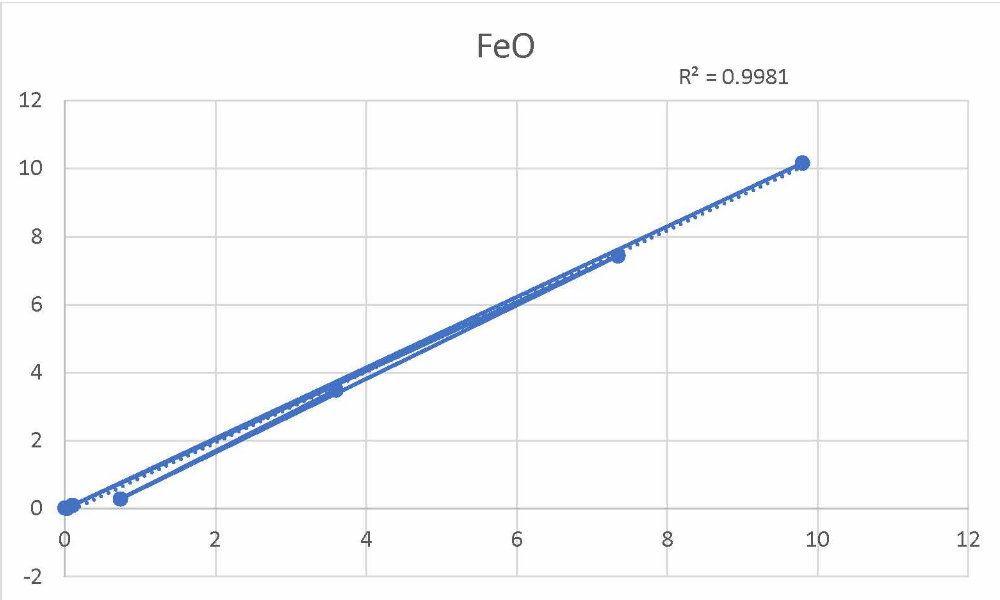

Figure C.7 Regression comparison of FeO weight percent concentrations collected on the Niton verses actual values of homogenous standards.

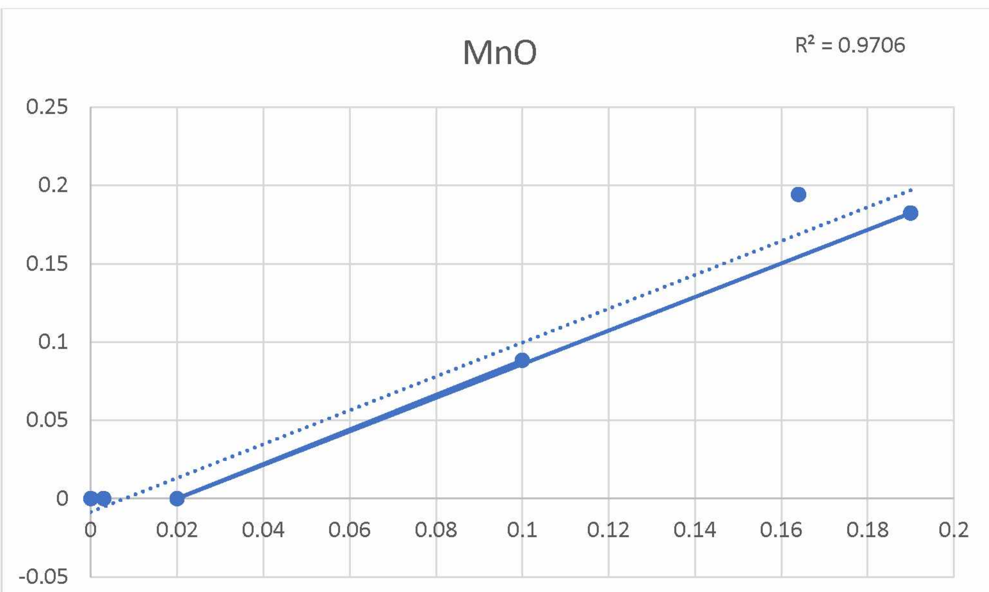

Figure C.8 Regression comparison of MnO weight percent concentrations collected on the Niton verses actual values of homogenous standards.

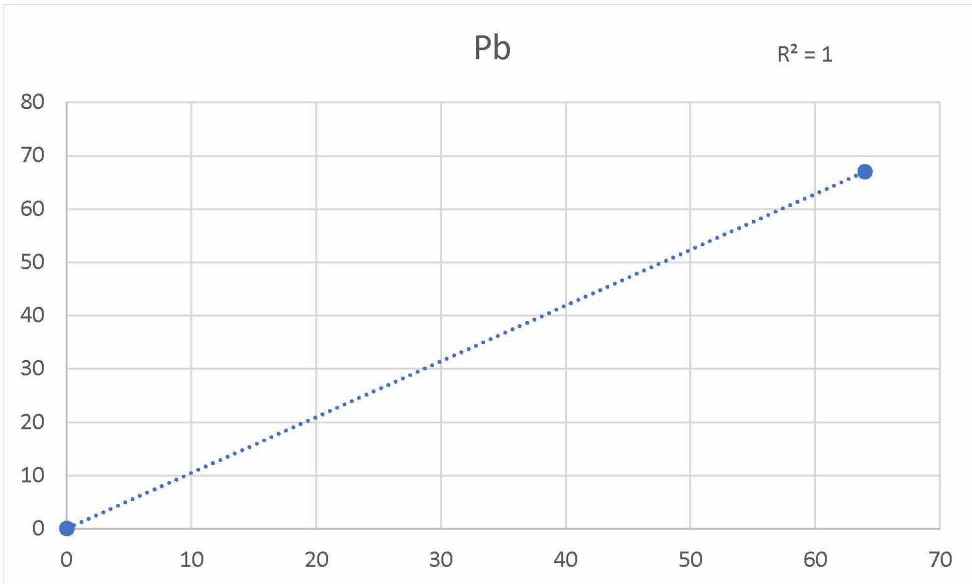

Figure C.9 Regression comparison of Pb parts per million (ppm) concentrations collected on the Niton verses actual values of homogenous standards.

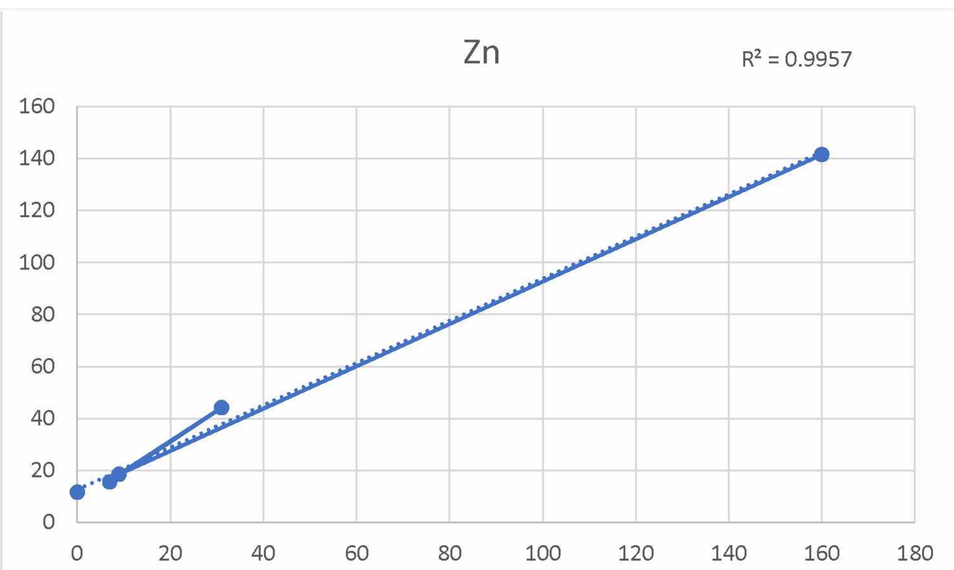

Figure C.10 Regression comparison of Zn ppm concentrations collected on the Niton verses actual values of homogenous standards.

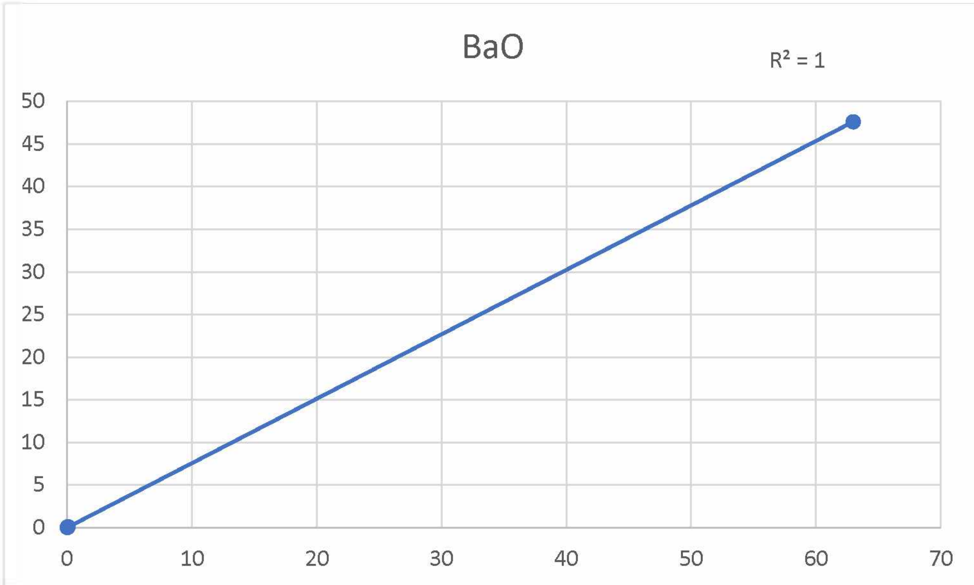

Figure C.11 Regression comparison of BaO weight percent concentrations collected on the Niton verses actual values of homogenous standards.

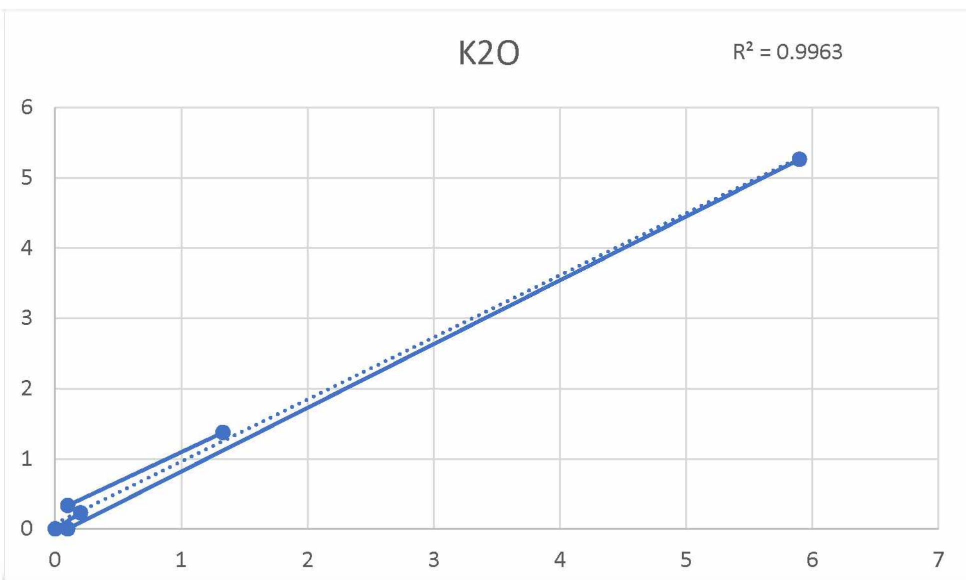

Figure C.12 Regression comparison of K2O weight percent concentrations collected on the Niton verses actual values of homogenous standards.

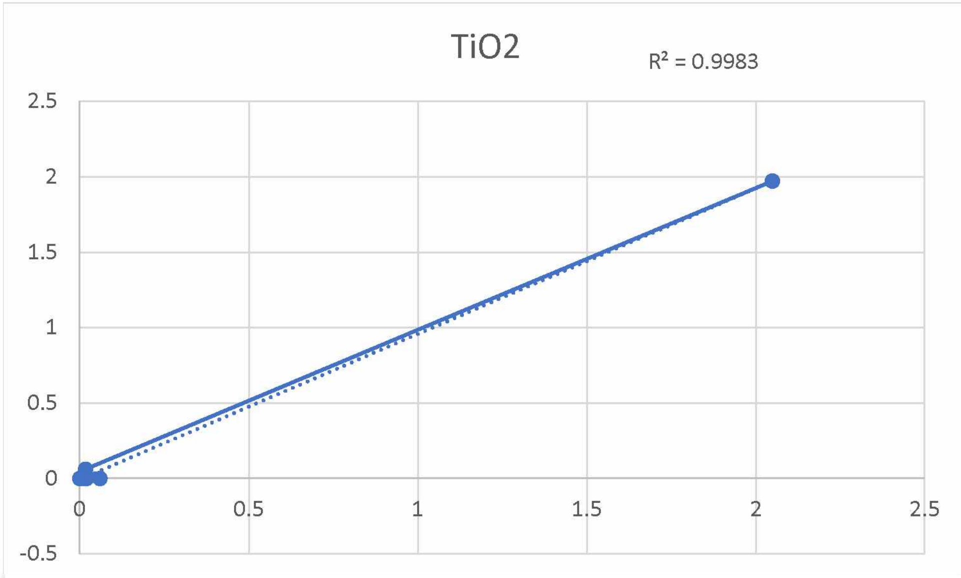

Figure C.13 Regression comparison of TiO2 weight percent concentrations collected on the Niton verses actual values of homogenous standards.

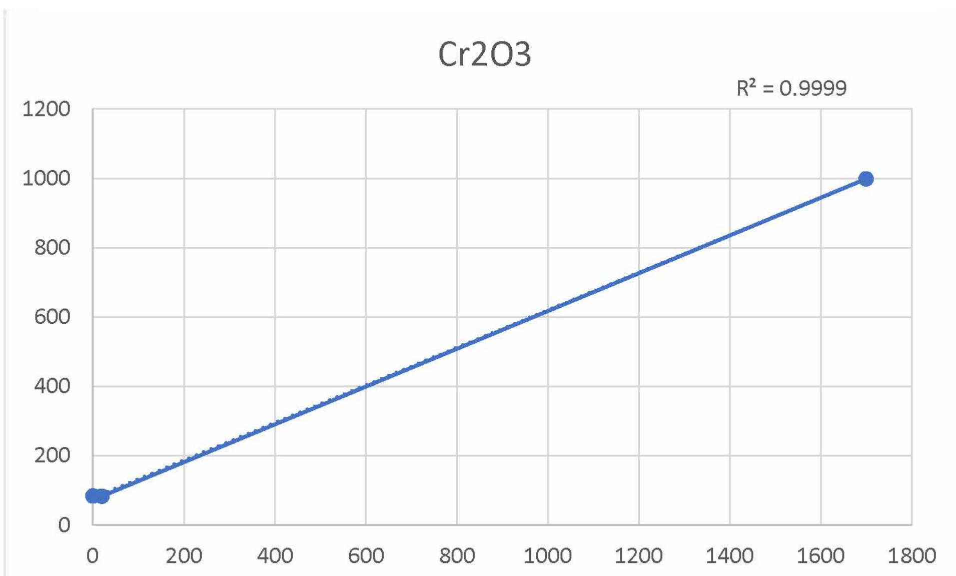

Figure C.14 Regression comparison of Cr2O3 weight percent concentrations collected on the Niton verses actual values of homogenous standards.

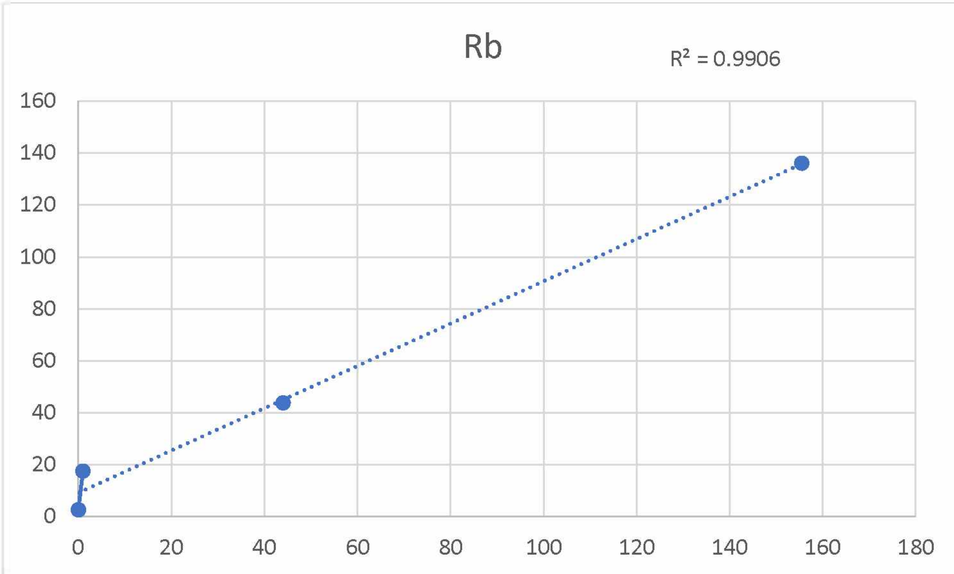

Figure C.15 Regression comparison of Rb ppm concentrations collected on the Niton verses actual values of homogenous standards.

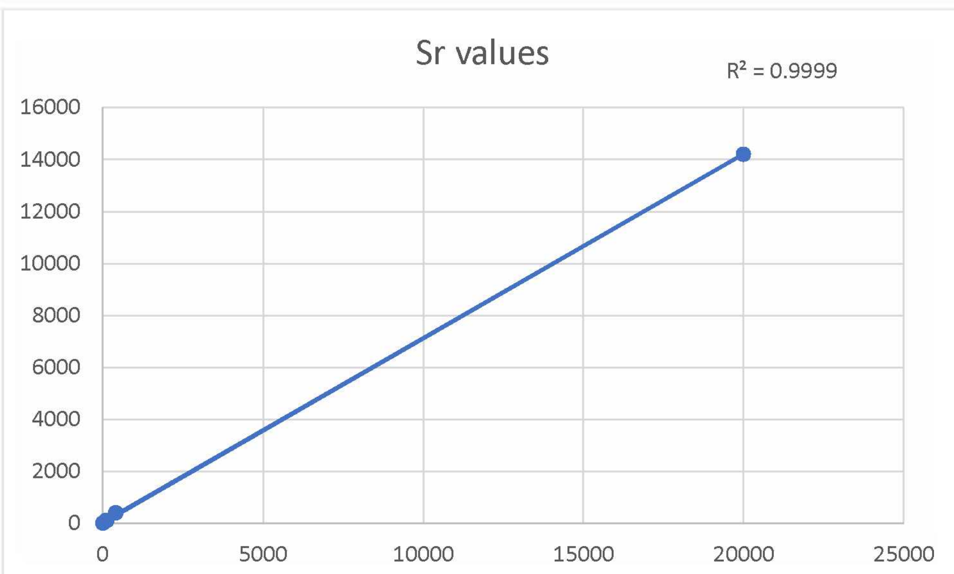

Figure C.16 Regression comparison of Sr ppm concentrations collected on the Niton verses actual values of homogenous standards.

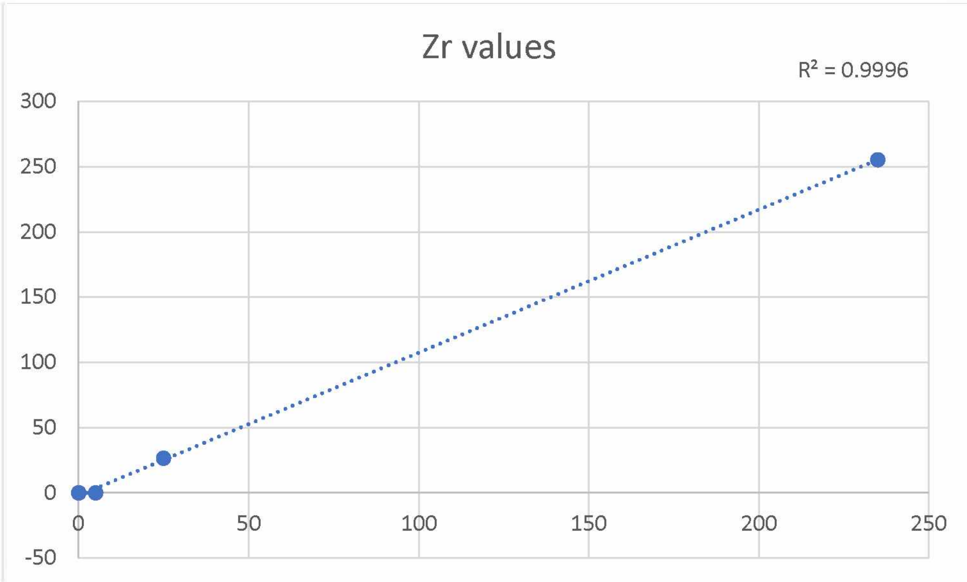

Figure C.17 Regression comparison of Zr ppm concentrations collected on the Niton verses actual values of homogenous standards.

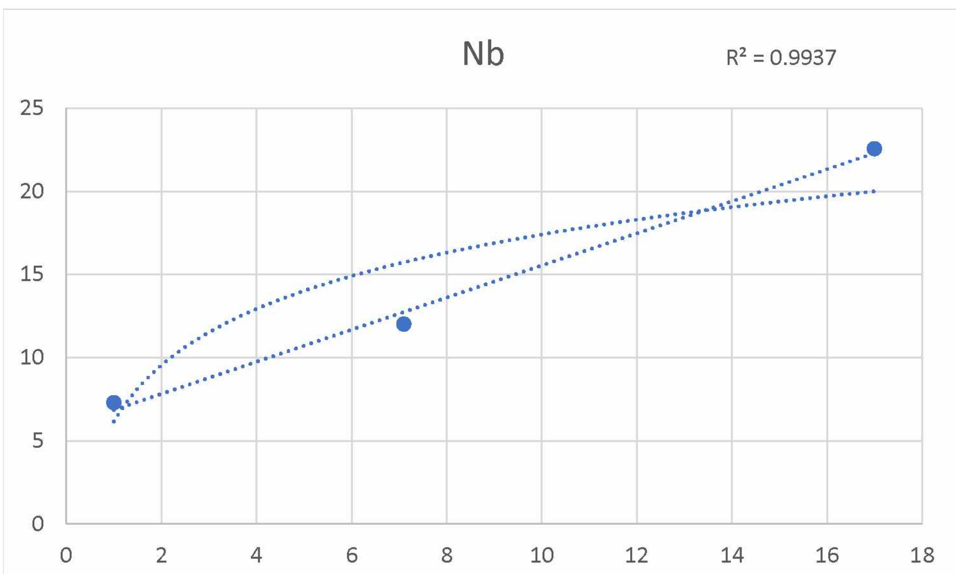

Figure C.18 Regression comparison of Nb ppm concentrations collected on the Niton verses actual values of homogenous standards.

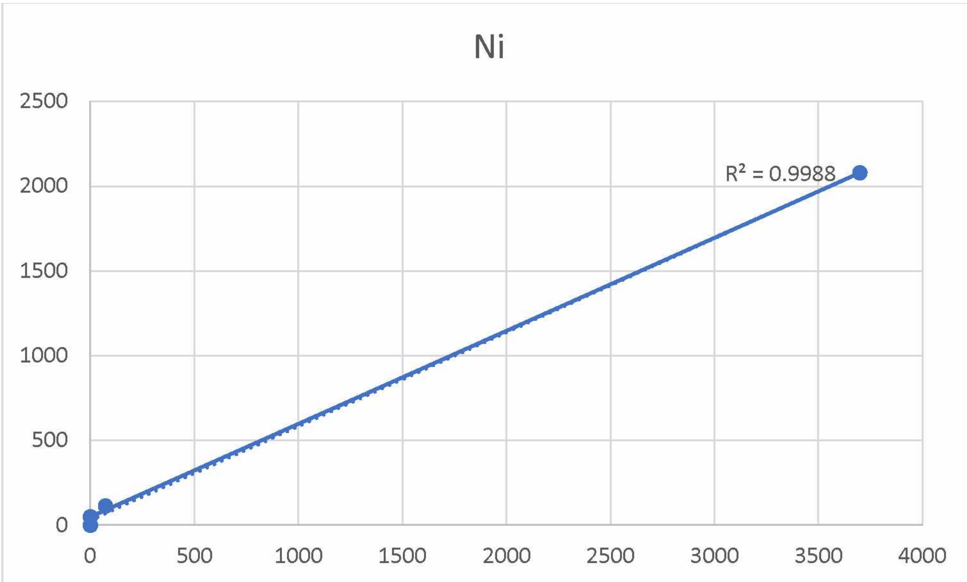

Figure C.19 Regression comparison of Ni ppm concentrations collected on the Niton verses actual values of homogenous standards.

Regression Plots for Comparing Niton Values to WD-XRF Values

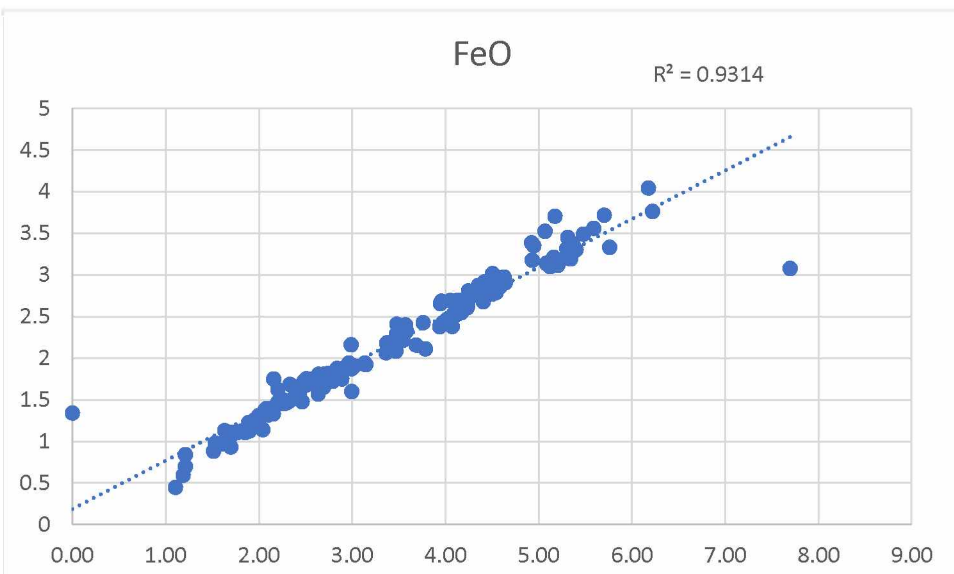

Figure C.20 Regression comparison of FeO weight percent concentrations collected on the Niton verses actual weight percent values of the same samples on the WD-XRF.

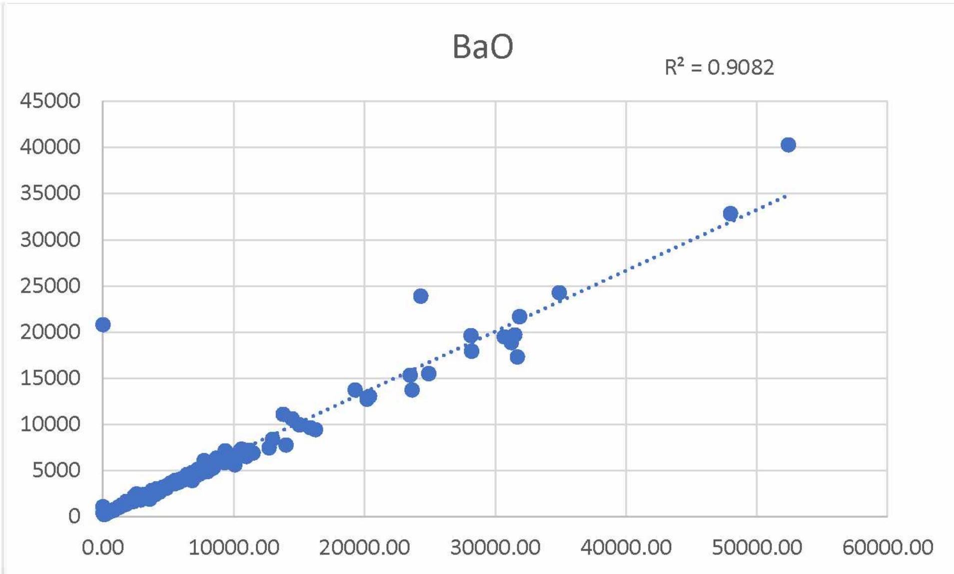

Figure C.21 Regression comparison of BaO weight percent concentrations collected on the Niton verses actual weight percent values of the same samples on the WD-XRF.

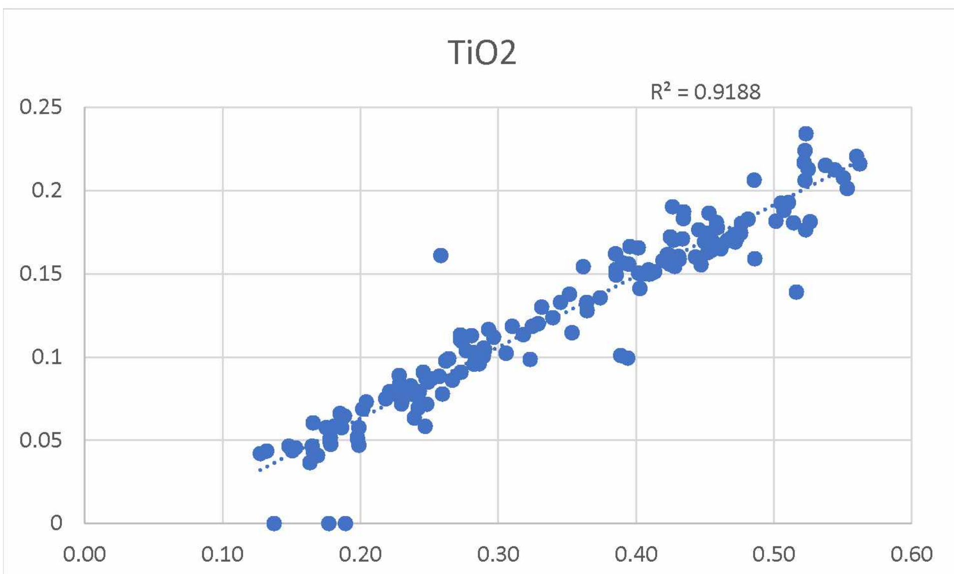

Figure C.22 Regression comparison of TiO2 weight percent concentrations collected on the Niton verses actual weight percent values of the same samples on the WD-XRF.

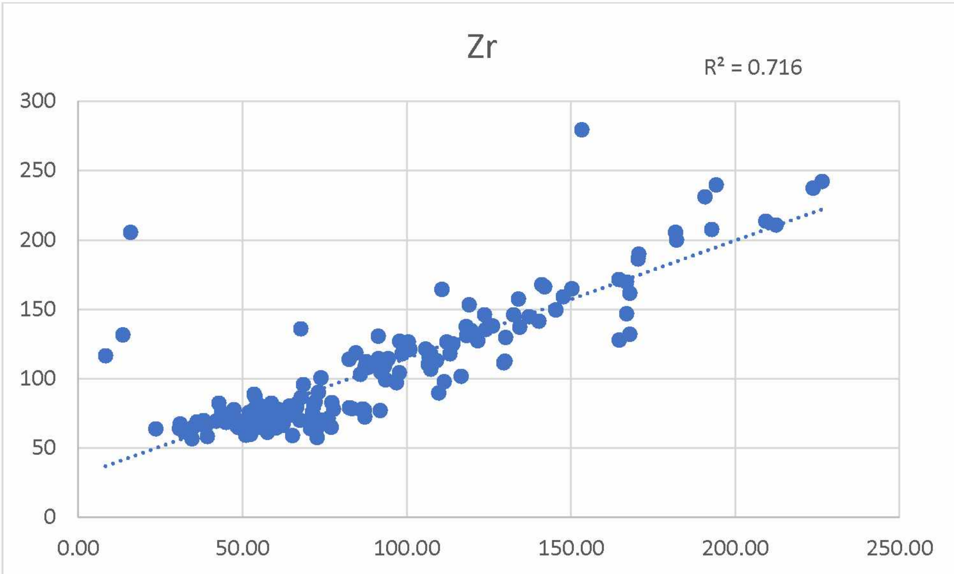

Figure C.23 Regression comparison of Zr ppm concentrations collected on the Niton verses actual ppm values of the same samples on the WD-XRF.

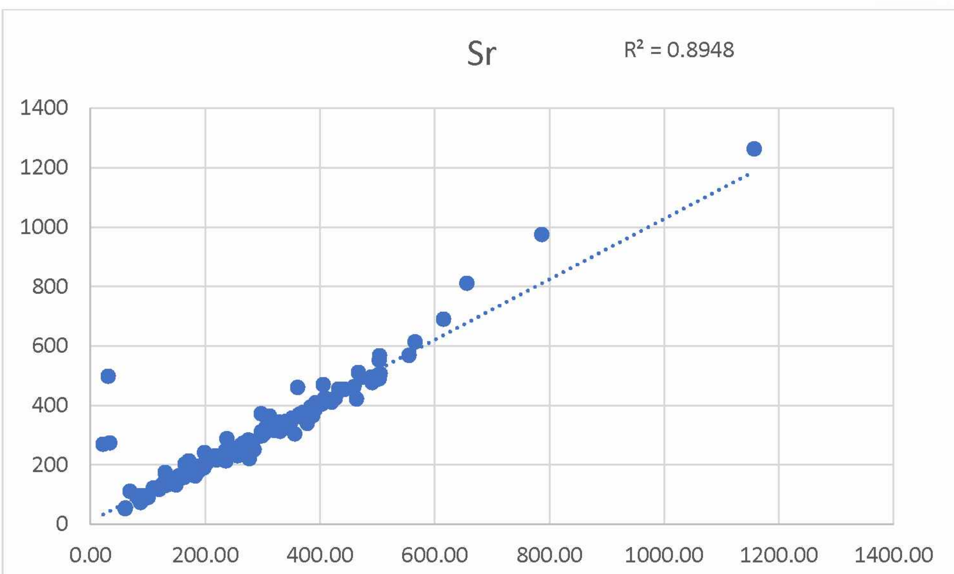

Figure C.24 Regression comparison of Sr ppm concentrations collected on the Niton verses actual ppm values of the same samples on the WD-XRF.

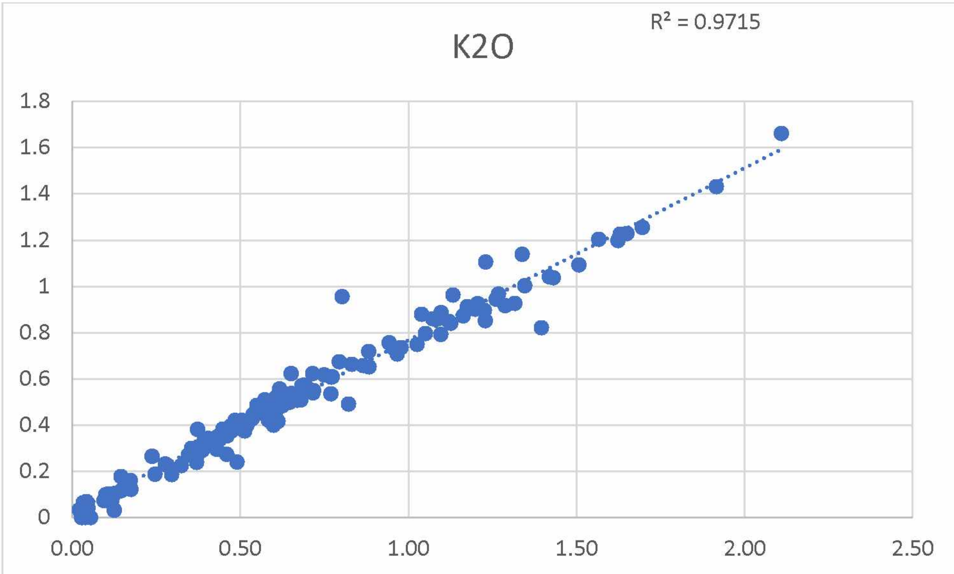

Figure C.25 Regression comparison of K2O weight percent concentrations collected on the Niton verses actual weight percent values of the same samples on the WD-XRF.

Appendix D

Raw Material Group Codes and Descriptions

Table D.1 Original raw material code qualitative groupings and descriptions.

Raw material Code	Munsell	Quality	Rock Type
A1	Yellowish gray 5Y7/2/ medium bluish gray 5B 5/1/ olive gray 5Y 4/1	M	Metamorphic
A19	Yellowish gray 5Y 8/1	L	Metamorphic
A2	Pale yellowish orange 10YR 8/6 with dark gray N3 speckles; dark yellowish brown 10YR 4/2; medium bluish gray 5B 5/1	M	Meta-tuff
B1	Med dark gray N4; grayish black N2	L	Meta-tuff
B3	Dusky yellowish brown 10YR 2/2 with dark yellowish orange 10YR 6/6 speckles	M	Meta-chert
B4	Brownish gray 5YR 4/1 through grayish black N2	H	Metamorphic
B5	Medium gray N5 with yellowish gray 5Y 8/1 quartz inclusions	H	Basalt
C1	Greenish gray 5GY 6/1 with moderate reddish brown 10R 4/6; light olive gray 5Y 6/1	H	Meta-chert
C2	Striped med. Light gray N6 and dark gray N3	H	Meta-chert
C21	Moderate yellowish brown 10YR 5/4	H	Chert
C22	Dark yellowish brown 10YR 4/2	H	Chert
C23	Brownish gray 5YR 4/1	H	Meta-chert
C24	Olive gray 5Y 4/1	H	Chert
C25	Grayish brown 5YR 3/2	H	Chert
C26	Dark reddish brown 10R 3/4	H	Chert
C9	Yellowish gray 5Y 7/2	H	Chert
CH1	Translucent dark yellowish orange 10YR 6/6	H	Chalcedony
CH2	Dark reddish brown 10R 3/4; blackish red 5R 2/2 with grayish pink 5R 8/2 inclusions	H	Chalcedony
CH3	Dark reddish brown 10R 3/4 with very dusky red 10R 2/2 splotches	H	Chalcedony
M1	Yellowish gray 5Y 8/1 and Light bluish gray 5B 7/1	H	Meta-chert

M10	Olive gray 5Y 4/1	M	Meta-chert
M2	Very pale orange 10YR 8/2, cortex is moderate reddish brown 10R 4/6 to Dark yellowish orange 10YR 6/6; one with medium bluish gray 5B 5/1 stripes; Yellowish gray 5Y 8/1	H	Meta-chert
M3	Pale yellowish brown 10YR 6/2 with dark gray N3 speckles	M	Metamorphic
M3	Light bluish gray 5B 7/1 and medium bluish gray 5B 5/1 with dark gray N3 speckles	M	Metamorphic
M4	Grayish orange 10YR 7/4 and Yellowish gray 5Y 8/1/ light greenish gray 5GY 8/1	H	Meta-chert
M5	Dark greenish gray 5G 4/1	H	Meta-chert
M6	Dark gray N3	H	Meta-chert
M7	Speckled pale yellowish brown 10YR 6/2 and dark gray N3	M	Metamorphic
M8	Light gray N7 and medium gray N5 stripes	H	Metamorphic
M9	Olive gray 5Y 4/1 with light olive gray 5Y 6/1 siliceous slabs	H	Metamorphic
Obsid 1	Grayish black to transparent	H	Obsidian
Q1	Very pale orange 10YR 8/2 and light gray N7 quartz crystals	L	Quartzite
Q2	cortex: very dusky purple 5RP 2/2, interior: pale red purple 5RP 6/2	M	Quartzite
Q3	Olive gray 5Y 4/1	M	Meta-tuff
Q4	Medium bluish gray 5B 5/1 and very light gray N8 speckles	M	Quartzite
R1	Pale yellowish brown 10YR 6/2 and Light olive gray 5Y 6/1	H	Metamorphic
R2	Light brownish gray 5YR 6/1 with brownish gray 5YR 4/1 speckles	H	Rhyolite
R3	between pinkish gray 5YR 8/1 and pale purple 5P 6/2	M	Rhyolite
S1	Moderate yellowish brown 10YR 5/4; Very pale orange 10YR 8/2	L	Metamorphic
S2	Medium dark gray N4 stripes/ light olive gray 5Y 6/1	M	Sandstone
R4	Greyish green rhyolite	H	Rhyolite
S3	Grayish tan microcrystalline sandstone with brown specs and portions fading from darker gray to lighter gray, macrocrystalline bluish quartz grains	M	Sandstone

Appendix E

Discriminant Function Data Analysis Adherence to Assumptions

Table E.1 Quarry compositional data adherence to DFA assumptions.

Quarries	Elements	N of cases	Normality	Kurtosis		Removed outliers	Secondary normality	Kurtosis
LMG Niton	S	3 out of 65	normal	0		no outliers		
LMG Niton	K_2O	62 out of 65	not normal	-1.3 bimodal		no outliers		
LMG Niton	CaO	65	not normal	27.6 leptokurtic		LMG 14-6, LMG 4-1	normal	0 (-1.11)
LMG Niton	TiO_2	65	normal	0		no outliers		
LMG Niton	V	65	normal	0		no outliers		
LMG Niton	Nb	65	not normal	-0.17 platykurtic		LMG 4-6	normal	0 (-0.32)
LMG Niton	BaO	65	not normal	-1.16 platykurtic		no outliers		

LMG Niton	LMG Niton	LMG Niton	LMG Niton	LMG Niton	LMG Niton	LMG Niton	LMG Niton
Cr2O3	Zr	Sr	Rb	Zn	Ni	FeO	MnO
65	65	65	59	65	65	65	65
normal	not normal	not normal	not normal	not normal	normal	normal	normal
2.44 platykurtic	0.63 platykurtic	12.6 leptokurtic	-0.86 platykurtic	62.6 leptokurtic	0	0	0
LMG 14-8, LMG 4-3, LMG 10 upper-4	LMG 14-8	LMG 14-7, LMG 14-8	no outliers	LMG 10 upper-3, LMG 11-4, LMG 11-2 LMG 11-6, LMG 14-7	no outliers	LMG 10 upper-5, LMG 10 upper-6, LMG 13-2	no outliers
normal	not	normal		normal		normal	
platykurtic	platykurtic	0 (-0.45)		0 (-0.12)		0 (0.40)	

LL Niton	LL Niton	LL Niton	LL Niton	LL Niton	LL Niton	LL Niton	LL Niton
MnO	BaO	Nb	V	TiO2	CaO	K2O	S
93	93	93	31	90	93	93	50 out of 93
not normal	not normal	not normal	normal	not normal	not normal	not normal	not normal
5.35 leptokurtic	5.81 leptokurtic	6.47 leptokurtic	0	0.21 platykurtic	16.3 leptokurtic	7.09 leptokurtic	6.8 leptokurtic
LL 4-3, LL 6-1, LL 6-2, LL 6-3, LL 6-4, LL 7u-4, LL 7u-5, LL 7u-6, LL 8-1, LL 8-4, LL 8-6	LL 4-2, LL 4-3, LL 4-4, LL4-5, LL 4-6, LL 5-2, LL 6-1, LL6-2, LL 6-3, LL 6-4, LL 7u-4, LL 7u-5, LL 7u-6, LL 8-3, LL 8-4, LL 8-5, LL 12-1, LL 13-1	LL 15-2, LL 19-1, LL 20-2, LL 21-2, LL 20-1, LL 18-5	no outliers	LL 15-2, LL 7u-5, LL 20-2	LL 12-1,LL 13-3, LL 13-5, LL 14-1, LL 6-2, LL7u-5, LL 7u-6, LL20-1, LL 6-6, LL7-2u, LL 13-4, LL 12-2, LL 10S-4	LL 15-2, LL 19-1, LL 20-2, LL 2-1, LL 21-1, LL 21-2, LL 2-2, LL 3-1, LL 20-1, LL 3-2, LL 7u-4, LL 7u-5, LL7u-6, LL8-4, LL 8-5	LL 16-1, LL 16-6, LL8-3, LL 8-6
normal	not normal	normal		normal	not normal	normal	not normal
0 (-0.02)	Platykurtic 0.37	0 (-0.49)		0 (-0.06)		0 (-0.11)	Platykurtic -0.898

LMG WD		LL Niton	LL Niton	LL Niton	LL Niton	LL Niton	LL Niton	LL Niton
Pb		Cr2O3	Zr	Sr	Rb	Zn	Ni	FeO
65		93	93	93	93	93	69	93
not normal		not normal	not normal	not normal	not normal	not normal	not normal	normal
21.06 leptokurtic		3.87 leptokurtic	2.63 leptokurtic	5.07 leptokurtic	5.18 leptokurtic	0.7 platykurtic	7.7 leptokurtic	0
LMG 13-6, LMG 14-1, LMG 4-6, LMG 8low-1		LL 6-1, LL 6-4, LL 6-3, LL 15-2, LL 4-2,LL 4-3, LL 4-5, LL 4-6, LL 5-2, LL 7u-4, LL 7u-5, LL 7u-6, LL 8-3, LL 8-4	LL 15-1, LL 15-2, LL 19-1, LL 20-, LL 20-2, LL 2-1, LL 21-2, LL 21-1, LL 2-2, LL 3-2, LL 7u-5, LL 8-4	LL 13-1, LL 4-2, LL 4-3, LL 4-5, LL 6-1, LL 6-2, LL 4-6, LL 8-4, LL 12-1	LL 15-2, LL 20-2, LL 2-1, LL 19-1, LL 20-1, LL 21-1, LL 21-2, LL 2-2, LL 8-5, LL 7u-5	LL 4-3, LL 5-2, LL 6-4, LL 6-3	LL 12-6, LL 16-2, LL 6-1, LL 6-2, LL 6-3, LL 6-4, LL 8-3, LL 4-3	LL 6-6, LL 8-4
ALL 0 = no		normal	normal	normal	normal	normal	normal	normal
		0 (0.09)	0 (-0.12)	0 (-0.22)	0 (-0.27)	0 (-0.21)	0 (-0.01)	0 (0.17)

LMG WD	W	65	not normal	55.54 leptokurtic		ALL LMG10b-2, LMG10u-2 , LMG5-1b, LMG 11-4, LMG 11-5, LMG 12-2, LMG 12-5, LMG1u-2, LMG 8w-2, LMG 9-2, LMG 4-1, LMG 4-3, LMG 8low-1, LMG 8low-2	ALL 0 = no	
LMG WD	BaO	65	not normal	-1.02 platykurtic		No outliers		
LMG WD	Mo	65	not normal	64.87 leptokurtic		LMG 15-1, LMG 8U-1, LMG 10U-3, LMG10U-6, LMG 7-2, LMG 9-2, LMG 10u-1, LMG 10u-2, LMG 10U-4, LMG 10U-5, LMG 4-6, LMG 4-4, LMG 1u-2, LMG 1u-1, LMG 3-1, LMG 3-2, LMG 11-1, LMG 11-5	ALL 0 = no	
LMG WD	Nb	65	not normal	20.31 leptokurtic		LMG10U-3, LMG10U-4, LMG12-5, LMG 4-2, LMG 4-6	normal	platykurtic - 0.25
LMG WD	Zr	65	normal	0.75 platykurtic		No outliers		
LMG WD	Y	65	not normal	10.48 leptokurtic		LMG 13-6, LMG 15-5, LMG 15-6, LMG 1u-1, LMG 4-4, LMG 8low-1	normal	Platykurtic - 0.90
LMG WD	Sr	65	not normal	8.52 leptokurtic		LMG 14-7, LMG 14-8	normal	platykurtic 0.39
LMG WD	Rb	65	not normal	23.03 leptokurtic		LMG 15-5, LMG 15-6, LMG 8low-1	not	platykurtic

LMG WD	LMG WD	LMG WD	LMG WD	LMG WD	LMG WD	LMG WD
MnO	FeO	Ni	Cu	Zn	Ga	As
65	65	65	65	65	65	65
normal	not normal	not normal	not normal	not normal	not normal	not normal
1.86 platykurtic	3.18 leptokurtic	62.17 leptokurtic	50.16 leptokurtic	32.05 leptokurtic	-1.67 platykurtic	29.5 leptokurtic
LMG 8u-1	LMG 8u-1, LMG 10u-5, LMG 10u-6	LMG 8u-1	LMG 8u-1, LMG 7-2, LMG 15-1, LMG 14-6, LMG 14-4, LMG 4-2, LMG 13-1, LMG 12-2	LMG 11-2, LMG 11-4, LMG 11-6, LMG 12-1, LMG 7-2, LMG 10u-3, LMG 10u-4	No outliers	LMG 11-3, LMG 12-4, LMG 15-6, LMG 15-5, LMG 8low-1, LMG 7-1
normal	normal	normal	normal	normal		ALL 0 = no
platykurtic -0.52	platykurtic 0.04	platykurtic -0.77	Platykurtic -0.53	Platykurtic		

LMG WD	LMG WD	LMG WD	LMG WD	LMG WD	LMG WD	LMG WD	LMG WD
SiO2	P2O5	S	K2O	CaO	TiO2	V	Cr2O3
65	65	65	65	65	65	65	65
normal	not normal	not normal	not normal	not normal	normal	normal	not normal
0.57 platykurtic	23.2 leptokurtic	37.9 leptokurtic	-1.28 platykurtic	27.5 leptokurtic	-0.67 platykurtic	9.31 leptokurtic	64.99 leptokurtic
LMG 13-1, LMG 13-5, LMG 13-6, LMG 14-7, LMG 14-8, LMG 4-3, LMG 6-2	LMG 14-4, LMG 14-8, LMG 10u-2, LMG 10u-3, LMG 10u-5, LMG 10u-6	LMG 13-2, LMG 14-4, LMG 14-6, LMG 8u-1, LMG 10u-5, LMG 10u-2, LMG 10u-3, LMG 13-3	No outliers	LMG 14-7, LMG 14-8	No outliers	LMG 11-1	LMG 8u-1
normal	normal	not normal		normal		normal	normal
platykurtic -0.48	Platykurtic -0.29	platykurtic 0.24		platykurtic -1.11		platykurtic -0.28	platykurtic 0.15

LMG WD	Al2O3	65	normal	0.75 platykurtic		LMG 6-2	normal	platykurtic 0.31
LMG WD	MgO	65	not normal	2.11 platykurtic		LMG 14-7, LMG 14-8, LMG 10u-5, LMG 10u-6,	normal	Platykurtic - 0.68
LMG WD	Na2O	65	not normal	-1.07 platykurtic		No outliers		
LL WD	Pb	93	not normal	55.03 leptokurtic		LL12-2, LL16-1, LL17-1, LL17-5, LL2-1, LL6-1u, LL9-6		
LL WD	W	93	not normal	1.47 platykurtic		LL10S-4, LL11-1, LL1-1, LL10N-2, LL11-3a, LL12-4, LL13-2, LL13-4, LL14-3, LL17-5, LL18-2, LL2-2, LL21-1, LL21-1, LL6-5b, LL6-6b, LL7-4b, LL8-1, LL8-6	not normal	platykurtic 0.54
LL WD	BaO	93	not normal	4.13 leptokurtic		LL12-1, LL13-1, LL4-2, LL4-3, LL4-4, LL4-5, LL4-6, LL6-1u, LL6-2u, LL6-3m, LL6-4m, LL7-4b, LL7-5b, LL7-6b, LL8-3, LL8-4, LL8-5	not normal	platykurtic 0.07
LL WD	Mo	93	not normal	10.77 leptokurtic		LL18-4, LL21-2, LL4-3, LL4-5	not	Platykurtic -0.19
LL WD	Nb	93	normal	0		LL14-5, LL14-6, LL16-6, LL4-5	Normal	platykurtic -0.73

LL WD	LL WD	LL WD	LL WD	LL WD	LL WD	LL WD	LL WD	LL WD
Ni	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
93	93	93	93	93	93	93	93	93
not normal	not normal	normal	not normal	not normal	not normal	not normal	normal	normal
0.63 platykurtic	22.35 leptokurtic	0	-1.37 platykurtic	23.58 leptokurtic	4.01 leptokurtic	2.54 platykurtic	0	0
LL6-1u, LL6-3m, LL6-4m, LL6-5b, LL7-1u, LL7-3u, LL8-6, LL9-5, LL11-1, LL16-2, LL4-3, LL5-2, LL6-2u, LL7-5b	LL12-4, LL13-3, LL4-2, LL8-1, LL9-1, LL11-6				LL19-1, LL2-2, ll19-2, LL20-2, LL21-1, LL21-2, LL6-2u, LL7-5b, LL7-6b, LL8-5, LL2-1,	LL4-3, LL6-1u, LL6-2u, LL8-4, LL12-1		LL19-1, LL2-2, LL20-2, LL21-1, LL18-6
normal	not				normal	not		normal
platykurtic -0.22	platykurtic 0.29				Platykurtic -0.2	platykurtic -0.0004		Platykurtic -0.46

LL WD	FeO	93	normal	0		LL7-3u	normal	Platykurtic
LL WD	MnO	93	not normal	53.2 leptokurtic		LL6-1u, LL6-2u, LL6-3, LL6-4m, LL6-5b, LL7-3u, LL7-4b, LL6-5b, LL7-3u, LL7-4b, LL7-5b, LL7-6b, LL8-1, LL8-4, LL8-6	normal	Platykurtic
LL WD	Cr2O3	93	not normal	92.6 leptokurtic		LL16-5, LL19-1, LL7-3u	normal	Platykurtic
LL WD	V	93	normal	0		LL7-5b	normal	Platykurtic
LL WD	TiO2	93	not normal	1.07 platykurtic		LL15-2, LL15-1, LL19-1, LL20-2, LL21-2, LL7-5b, LL20-1	normal	platykurtic
LL WD	CaO	93	not normal	16.3 leptokurtic		LL13-3, LL13-2, LL13-4, LL15-2, LL6-1u, LL7-1u, LL7-4b, LL7-5b, LL-76b, LL8-4, LL7-3u, LL1-1, LL10S-4, LL12-1, LL12-3, LL12-6, LL12-5, LL18-6	normal	platykurtic 0.07
LL WD	K2O	93	not normal	7.67 leptokurtic		LL15-2, LL19-1, LL2-1, LL2-2, LL20-2, LL20-1, LL21-1, LL21-2, LL7-4b, LL7-5b, LL7-6b, LL8-6, LL3-1, LL19-2, LL3-2	normal	Platykurtic -0.49

LL WD	LL WD	LL WD	LL WD	LL WD	LL WD
Na2O	MgO	Al2O3	SiO2	P2O5	S
93	93	93	93	93	93
not normal	not normal	not normal	not normal	not normal	not normal
5.94 leptokurtic	5.1 leptokurtic	6.62 leptokurtic	7.92 leptokurtic	68.95 leptokurtic	8.82 leptokurtic
LL1-1, LL7-1u, LL7-4b, LL7-6b, LL8-4, LL8-5	LL1-1, LL1-2, LL4-3, LL5-2, LL7-2u, LL7-4b, LL-5b, LL7-6b	LL15-2, LL20-2, LL7-4b, LL7-5b, LL7-6b, LL8-4, LL19-1, LL2-2	LL7-4b, LL7-5b, LL7-6b, LL8-5, LL6-1u, LL20-2, LL7-2u, LL15-2	LL1-1, LL4-3, LL5-2, LL7-5b, LL7-6b, LL7-4b, LL8-4, LL10S, LL12-5, LL3-2	LL16-1, LL16-6, LL6-1u, LL6-2u, LL4-3, LL7-2u, LL9-6, LL2-2, LL4-4, LL4-5, LL4-6, LL5-2, LL4-2, LL1-1, LL1-2
normal	not normal	not normal	not normal	not normal	normal
platykurtic 0.15	platykurtic -0.45	platykurtic 0.15	platykurtic -0.024	platykurtic 0.246	platykurtic -0.62

Appendix F

Homogeneity of Group Variance

Below are the results to test for homogeneity of group variances post DFA group assignments for the quarry samples analyzed on the Niton ED-XRF. Groups are (1) Landmark Gap Quarry, (2) Long Tangle Lake Quarry. Null hypothesis and homogeneity of group variance rejected was for Zr, Sr, Rb, Zn, MnO, BaO, Nb, Cr2O3, TiO2, CaO, K2O. The null hypothesis was accepted for FeO.

Table F.1 Test of homogeneity of variances for the quarry compositions collected by the Niton.

	Levene Statistic	df1	df2	Sig.
Zr	90.724	1	143	.000
Sr	7.633	1	145	.006
Rb	134.251	1	140	.000
Zn	26.532	1	147	.000
FeO	.836	1	152	.362
MnO	28.015	1	145	.000
BaO	41.360	1	138	.000
Nb	58.087	1	149	.000
Cr2O3	4.014	1	139	.047
TiO2	4.675	1	150	.032
CaO	165.197	1	141	.000
K2O	224.349	1	138	.000

Having shown that there is heterogeneity in group variance the consistency of the group assignments must be tested to ensure the validity of the Long Tangle Lake and Landmark Gap Quarry groups.

Table F.2 Tests of consistency of group assignments.

Elements/Oxides	Test
K_2O	Mann Whitney
CaO	Mann Whitney
TiO_2	Unequal Variance T
Nb	Unequal Variance T
BaO	Mann Whitney
FeO	Student's T
Ni	Unequal Variance T
Zn	Unequal Variance T
Rb	Mann Whitney
Sr	Unequal Variance T
Zr	Mann Whitney
Cr_2O_3	Unequal Variance T

Rejecting the null hypothesis when $p<0.05$ means that there is a significant difference between groups. The null hypothesis can be rejected for all elements except K_2O and Rb. Therefore, there is a significant difference between all groups based on CaO, TiO_2, Nb, BaO, MnO, FeO, Ni, Zn, Sr, Zr, and Cr_2O_3.

Table F.3 Results of Mann Whitney U test.

	Zr	Rb	BaO	CaO	K2O
Mann-Whitney U	0	2012.5	73	0	2404
Wilcoxon W	3321	3782.5	2218	3240	5485
Z	-10.321	-1.805	-9.879	-10.247	-0.059
Asymp. Sig. (2-tailed)	0	0.071	0	0	0.953

Table F.4 Results of Student's T-test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
FeO	Equal variances assumed	.836	.362	19.371	152	.000	1.29	.066	1.16	1.42
	Equal variances not assumed			19.860	141.526	.000	1.29	.065	1.16	1.42

Table F.5 Results of unequal variance T-test.

		Statistic[a]	df1	df2	Sig.
Sr		102.818	1	108.816	0
Zn		145.909	1	135.773	0
MnO		51.981	1	121.341	0
Nb		196.217	1	75.811	0
Cr2O3		37.595	1	136.551	0
TiO2		353.935	1	149.802	0

Appendix G

Results of Stepwise DFA of WD-XRF Analysis of Quarry Samples

Table G.1 DFA group statistics of WD-XRF compositions of quarry samples.

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	21.284[a]	100.0	100.0	0.977
a. First 1 canonical discriminant functions were used in the analysis.				
Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.045	257.622	8	0.000

Table G.2 Classification function coefficients for groups of WD-XRF compositions of quarry samples.

	Group	
	Landmark Gap Quarry	Long Tangle Lake Quarry
K2O	12.871	-5.977
CaO	24.723	-13.644
MnO	-34.871	20.374
FeO	14.862	5.163
Zn	.060	.316
Rb	-.105	.282
Sr	.013	.068
Zr	.239	.147
(Constant)	-74.478	-30.108

Table G.3 Classification results of WD-XRF compositions of quarry samples.

		Group	Predicted Group Membership		Total
			Landmark Gap Quarry	Long Tangle Lake Quarry	
Original	Count	Landmark Gap Quarry	50	0	50
		Long Tangle Lake Quarry	0	56	56
	%	Landmark Gap Quarry	100	0	100
		Long Tangle Lake Quarry	0	100	100
Cross-validated[b]	Count	Landmark Gap Quarry	50	0	50
		Long Tangle Lake Quarry	0	56	56
	%	Landmark Gap Quarry	100	0	100
		Long Tangle Lake Quarry	.0	100	100

Table G.4 Descriptive statistics of WD-XRF quarry group compositions.

Group		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Landmark Gap Quarry	K2O	0.69	0.57	44	44.000
	CaO	1.53	0.37	44	44.000
	TiO2	0.46	0.05	44	44.000
	V	141.55	26.73	44	44.000
	Cr2O3	115.88	21.47	44	44.000
	MnO	0.09	0.02	44	44.000
	FeO	4.62	0.60	44	44.000
	Zn	35.21	7.71	44	44.000
	Rb	26.08	20.67	44	44.000
	Sr	335.35	96.87	44	44.000
	Zr	131.87	32.55	44	44.000
	Nb	9.42	3.09	44	44.000
	BaO	1557.49	1285.49	44	44.000
Long Tangle Lake Quarry	K2O	0.59	0.10	45	45.000
	CaO	0.15	0.04	45	45.000
	TiO2	0.25	0.05	45	45.000
	V	85.80	31.90	45	45.000
	Cr2O3	55.96	18.28	45	45.000
	MnO	0.14	0.06	45	45.000
	FeO	2.58	0.63	45	45.000
	Zn	61.79	17.32	45	45.000
	Rb	28.54	4.68	45	45.000
	Sr	174.59	63.12	45	45.000
	Zr	58.55	15.09	45	45.000

	Nb	5.42	2.24	45	45.000
	BaO	7660.38	3458.57	45	45.000
Total	K2O	0.64	0.40	89	89.000
	CaO	0.83	0.74	89	89.000
	TiO2	0.35	0.12	89	89.000
	V	113.36	40.54	89	89.000
	Cr2O3	85.58	36.06	89	89.000
	MnO	0.12	0.05	89	89.000
	FeO	3.59	1.20	89	89.000
	Zn	48.65	18.91	89	89.000
	Rb	27.32	14.87	89	89.000
	Sr	254.07	114.50	89	89.000
	Zr	94.80	44.61	89	89.000
	Nb	7.40	3.35	89	89.000
	BaO	4643.22	4025.45	89	89.000

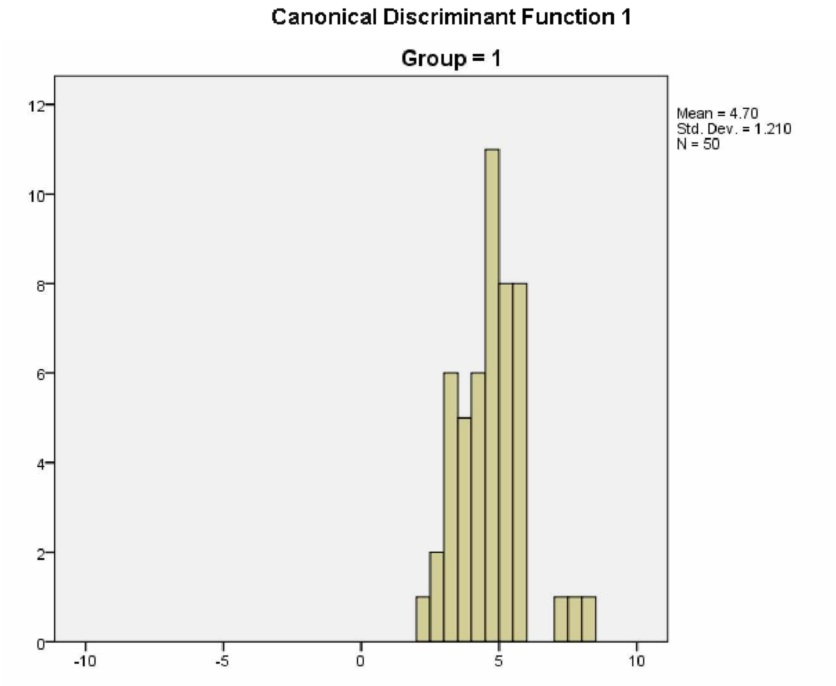

Figure G.1 Landmark Gap Quarry WD-XRF compositional group function.

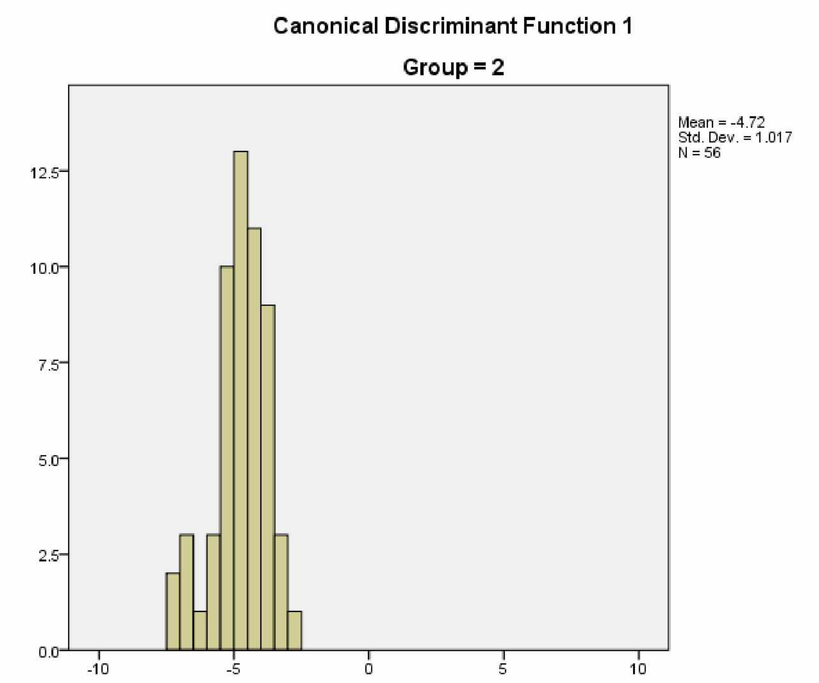

Figure G.2 Long Tangle Lake Quarry WD-XRF compositional group function.

Table G.5 DFA stepwise statistics of the WD-XRF quarry compositions.

Stepwise Statistics										
Variables Entered/Removed[a,b,c,d]										
Step	Entered	Removed	Wilks' Lambda							
			Statistic	df1	df2	df3	Exact F			
							Statistic	df1	df2	Sig.
1	CaO		0.122	1	1	87.000	628.273	1	87.000	0.000
2	TiO2		0.078	2	1	87.000	509.459	2	86.000	0.000
3	Zn		0.072	3	1	87.000	364.886	3	85.000	0.000
4	FeO		0.063	4	1	87.000	311.212	4	84.000	0.000
5	Sr		0.058	5	1	87.000	269.195	5	83.000	0.000
6		TiO2	0.059	4	1	87.000	332.652	4	84.000	0.000
7	Zr		0.054	5	1	87.000	290.555	5	83.000	0.000
8	K2O		0.051	6	1	87.000	254.267	6	82.000	0.000
9	Rb		0.047	7	1	87.000	232.078	7	81.000	0.000
10	MnO		0.045	8	1	87.000	212.844	8	80.000	0.000
At each step, the variable that minimizes the overall Wilks' Lambda is entered.										
a. Maximum number of steps is 26.										
b. Minimum partial F to enter is 3.84.										
c. Maximum partial F to remove is 2.71.										
d. F level, tolerance, or VIN insufficient for further computation.										

Table G.6 DFA stepwise statistics of the WD-XRF quarry compositions for variables in analysis.

Variables in the Analysis				
Step		Tolerance	F to Remove	Wilks' Lambda
1	CaO	1.000	628.273	
2	CaO	0.999	122.669	0.189
	TiO2	0.999	48.393	0.122
3	CaO	0.998	107.997	0.164
	TiO2	0.997	39.746	0.106
	Zn	0.996	6.817	0.078
4	CaO	0.995	88.401	0.130
	TiO2	0.686	5.265	0.067
	Zn	0.802	14.495	0.074
	FeO	0.599	11.750	0.072
5	CaO	0.434	66.525	0.105
	TiO2	0.637	1.853	0.059
	Zn	0.786	16.240	0.069
	FeO	0.594	12.348	0.067
	Sr	0.418	7.329	0.063
6	CaO	0.452	90.421	0.123
	Zn	0.867	24.802	0.077
	FeO	0.866	34.596	0.084
	Sr	0.450	11.026	0.067
7	CaO	0.449	64.151	0.096
	Zn	0.845	16.049	0.064
	FeO	0.848	36.558	0.078
	Sr	0.450	9.892	0.060

	Zr	0.919	8.195	0.059
8	CaO	0.419	70.959	0.095
	Zn	0.842	16.060	0.061
	FeO	0.842	29.628	0.069
	Sr	0.445	7.507	0.056
	Zr	0.896	5.484	0.054
	K2O	0.768	4.882	0.054
9	CaO	0.404	75.449	0.092
	Zn	0.836	16.550	0.057
	FeO	0.827	31.264	0.066
	Sr	0.420	10.127	0.053
	Zr	0.896	5.217	0.051
	K2O	0.198	10.749	0.054
	Rb	0.203	5.996	0.051
10	CaO	0.404	67.691	0.083
	Zn	0.780	9.503	0.050
	FeO	0.762	36.192	0.065
	Sr	0.419	8.652	0.050
	Zr	0.895	4.678	0.047
	K2O	0.195	11.907	0.052
	Rb	0.201	6.645	0.049
	MnO	0.783	4.667	0.047

Table G.7 DFA stepwise statistics of the WD-XRF quarry compositions for variables not in analysis.

Variables Not in the Analysis					
Step		Tolerance	Min. Tolerance	F to Enter	Wilks' Lambda
0	K2O	1.000	1.000	1.234	0.986
	CaO	1.000	1.000	628.273	0.122
	TiO2	1.000	1.000	373.671	0.189
	V	1.000	1.000	79.666	0.522
	Cr2O3	1.000	1.000	201.242	0.302
	MnO	1.000	1.000	36.115	0.707
	FeO	1.000	1.000	246.452	0.261
	Zn	1.000	1.000	86.841	0.500
	Rb	1.000	1.000	0.603	0.993
	Sr	1.000	1.000	86.409	0.502
	Zr	1.000	1.000	187.281	0.317
	Nb	1.000	1.000	48.941	0.640
	BaO	1.000	1.000	120.676	0.419
1	K2O	0.805	0.805	22.167	0.097
	TiO2	0.999	0.999	48.393	0.078
	V	1.000	1.000	8.841	0.110
	Cr2O3	0.999	0.999	26.331	0.093
	MnO	1.000	1.000	5.058	0.115
	FeO	0.999	0.999	33.086	0.088
	Zn	0.998	0.998	12.918	0.106
	Rb	0.857	0.857	10.582	0.108
	Sr	0.457	0.457	22.115	0.097
	Zr	0.986	0.986	13.945	0.105
	Nb	0.998	0.998	8.050	0.111

	BaO	0.997	0.997	11.327	0.107
2	K2O	0.753	0.753	5.870	0.073
	V	0.778	0.778	0.074	0.078
	Cr2O3	0.863	0.863	4.803	0.074
	MnO	0.996	0.995	2.084	0.076
	FeO	0.744	0.744	4.258	0.074
	Zn	0.996	0.996	6.817	0.072
	Rb	0.730	0.730	0.245	0.078
	Sr	0.427	0.427	5.712	0.073
	Zr	0.958	0.958	4.313	0.074
	Nb	0.994	0.994	3.614	0.075
	BaO	0.962	0.962	2.795	0.075
3	K2O	0.748	0.748	6.463	0.067
	V	0.756	0.756	0.025	0.072
	Cr2O3	0.859	0.859	3.712	0.069
	MnO	0.863	0.863	0.252	0.072
	FeO	0.599	0.599	11.750	0.063
	Rb	0.726	0.726	0.432	0.072
	Sr	0.421	0.421	6.710	0.067
	Zr	0.914	0.914	2.200	0.070
	Nb	0.993	0.993	3.168	0.069
	BaO	0.958	0.958	3.139	0.069
4	K2O	0.741	0.594	7.141	0.058
	V	0.696	0.551	0.624	0.063
	Cr2O3	0.784	0.547	0.795	0.063
	MnO	0.748	0.520	3.069	0.061
	Rb	0.718	0.586	0.933	0.063
	Sr	0.418	0.418	7.329	0.058

	Zr	0.839	0.550	5.731	0.059
	Nb	0.966	0.583	4.919	0.060
	BaO	0.957	0.599	3.095	0.061
5	K2O	0.740	0.396	6.005	0.054
	V	0.696	0.418	0.610	0.058
	Cr2O3	0.783	0.417	0.877	0.057
	MnO	0.748	0.418	2.830	0.056
	Rb	0.707	0.412	0.378	0.058
	Zr	0.832	0.414	6.378	0.054
	Nb	0.966	0.418	4.299	0.055
	BaO	0.890	0.388	1.062	0.057
6	K2O	0.788	0.425	7.567	0.054
	TiO2	0.637	0.418	1.853	0.058
	V	0.756	0.446	0.142	0.059
	Cr2O3	0.807	0.450	1.371	0.058
	MnO	0.796	0.448	3.977	0.057
	Rb	0.803	0.430	1.117	0.059
	Zr	0.919	0.449	8.195	0.054
	Nb	0.984	0.449	5.180	0.056
	BaO	0.900	0.410	1.407	0.058
7	K2O	0.768	0.419	4.882	0.051
	TiO2	0.577	0.414	0.232	0.054
	V	0.709	0.446	1.136	0.053
	Cr2O3	0.803	0.449	1.677	0.053
	MnO	0.796	0.448	3.522	0.052
	Rb	0.787	0.430	0.381	0.054
	Nb	0.761	0.448	0.971	0.053
	BaO	0.887	0.409	0.649	0.054

8	TiO2	0.551	0.395	0.000	0.051
	V	0.671	0.411	2.457	0.050
	Cr2O3	0.791	0.418	1.004	0.050
	MnO	0.791	0.419	4.010	0.049
	Rb	0.203	0.198	5.996	0.047
	Nb	0.761	0.418	1.029	0.050
	BaO	0.807	0.393	2.215	0.050
9	TiO2	0.508	0.187	0.491	0.047
	V	0.666	0.190	2.948	0.046
	Cr2O3	0.791	0.198	1.037	0.047
	MnO	0.783	0.195	4.667	0.045
	Nb	0.754	0.196	1.449	0.047
	BaO	0.805	0.195	1.718	0.046
10	TiO2	0.472	0.187	0.015	0.045
	V	0.664	0.187	3.185	0.043
	Cr2O3	0.791	0.194	1.054	0.044
	Nb	0.753	0.193	1.481	0.044
	BaO	0.785	0.193	0.906	0.044

Table G.8 DFA stepwise Wilks' Lambda of the WD-XRF quarry compositions groups.

Step	Number of Variables	Lambda	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	1	0.122	1	1	87	628.273	1	87.000	0.000
2	2	0.078	2	1	87	509.459	2	86.000	0.000
3	3	0.072	3	1	87	364.886	3	85.000	0.000
4	4	0.063	4	1	87	311.212	4	84.000	0.000
5	5	0.058	5	1	87	269.195	5	83.000	0.000
6	4	0.059	4	1	87	332.652	4	84.000	0.000
7	5	0.054	5	1	87	290.555	5	83.000	0.000
8	6	0.051	6	1	87	254.267	6	82.000	0.000
9	7	0.047	7	1	87	232.078	7	81.000	0.000
10	8	0.045	8	1	87	212.844	8	80.000	0.000

Appendix H

Statistics for Stepwise DFA of Niton Analysis of Quarry Samples

Each sample was given a case number and the samples that did not contribute to the quarry groupings in that they did not have an element necessary for distinguishing the two groups, were statistically removed in the DFA analysis.

Table H.1 DFA group statistics of Niton compositions of quarry samples.

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	16.588[a]	100.0	100.0	0.971
a. First 1 canonical discriminant functions were used in the analysis.				
Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.057	270.953	5	0.000

Table H.2 Standardized canonical discriminant function coefficients for groups of Niton compositions of quarry samples.

Standardized Canonical Discriminant Function Coefficients	
	Function
	1
Zr	0.343
Zn	-0.460
FeO	0.670
MnO	-0.246
CaO	0.708

Table H.3 Descriptive statistics and equality of group means of Niton quarry group compositions.

Quarry		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Landmark Gap Quarry	Zr	142.27	33.89	46	46.000
	Sr	344.01	98.97	46	46.000
	Rb	26.30	20.46	46	46.000
	Zn	35.55	5.94	46	46.000
	FeO	2.92	0.37	46	46.000
	MnO	0.04	0.01	46	46.000
	BaO	1419.40	789.07	46	46.000
	Nb	16.28	3.96	46	46.000
	Cr2O3	88.50	10.75	46	46.000
	TiO2	0.17	0.02	46	46.000
	CaO	0.92	0.22	46	46.000
	K2O	0.59	0.40	46	46.000

Long Tangle Lake Quarry	Zr	71.45	8.53	53	53.000
	Sr	182.92	55.74	53	53.000
	Rb	27.17	5.15	53	53.000
	Zn	54.61	12.99	53	53.000
	FeO	1.63	0.45	53	53.000
	MnO	0.07	0.03	53	53.000
	BaO	5209.02	1998.61	53	53.000
	Nb	8.99	1.57	53	53.000
	Cr2O3	98.84	13.44	53	53.000
	TiO2	0.09	0.02	53	53.000
	CaO	0.09	0.03	53	53.000
	K2O	0.46	0.09	53	53.000
Total	Zr	104.36	42.74	99	99.000
	Sr	257.77	112.55	99	99.000
	Rb	26.76	14.37	99	99.000
	Zn	45.75	14.03	99	99.000
	FeO	2.23	0.77	99	99.000
	MnO	0.06	0.03	99	99.000
	BaO	3448.19	2452.39	99	99.000
	Nb	12.38	4.68	99	99.000
	Cr2O3	94.03	13.25	99	99.000
	TiO2	0.13	0.05	99	99.000
	CaO	0.48	0.44	99	99.000
	K2O	0.52	0.28	99	99.000
Tests of Equality of Group Means					
	Wilks' Lambda	F	df1	df2	Sig.
Zr	0.310	215.958	1	97	0.000

Sr	0.485	102.902	1	97	0.000
Rb	0.999	0.089	1	97	0.766
Zn	0.536	83.835	1	97	0.000
FeO	0.287	240.904	1	97	0.000
MnO	0.786	26.444	1	97	0.000
BaO	0.400	145.529	1	97	0.000
Nb	0.390	151.798	1	97	0.000
Cr2O3	0.847	17.513	1	97	0.000
TiO2	0.201	385.688	1	97	0.000
CaO	0.116	735.678	1	97	0.000
K2O	0.946	5.573	1	97	0.020

Table H.4 Niton quarry sample group assignments with the Landmark Gap Quarry samples labeled Group 1 and the Long Tangle Lake Quarry samples labeled group 2.

			Highest Group					Second Highest Group			Discriminant Scores
				P(D>d | G=g)							
	Case Number	Actual Group	Predicted Group	p	df	P(G=g | D=d)	Squared Mahalanobis Distance to Centroid	Group	P(G=g | D=d)	Squared Mahalanobis Distance to Centroid	Function 1
Original	1	1	1	.113	1	1.000	2.509	2	.000	42.240	2.743
	2	1	1	.192	1	1.000	1.703	2	.000	45.944	3.022
	3	1	1	.397	1	1.000	.717	2	.000	52.363	3.480
	4	1	1	.493	1	1.000	.469	2	.000	54.737	3.643
	6	1	1	.318	1	1.000	.997	2	.000	82.476	5.326
	9	1	1	.318	1	1.000	.996	2	.000	82.468	5.325
	10	1	1	.999	1	1.000	.000	2	.000	65.357	4.329

	11	1	1	.352	1	1.000	.865	2	.000	81.237	5.257
	13	1	1	.052	1	1.000	3.779	2	.000	37.690	2.383
	15	1	1	.059	1	1.000	3.554	2	.000	38.415	2.442
	17	1	1	.367	1	1.000	.815	2	.000	51.561	3.425
	18	1	1	.623	1	1.000	.242	2	.000	73.532	4.819
	19	1	1	.197	1	1.000	1.666	2	.000	87.874	5.618
	20	1	1	.285	1	1.000	1.144	2	.000	83.776	5.397
	21	1	1	.320	1	1.000	.989	2	.000	82.407	5.322
	22	1	1	.045	1	1.000	4.022	2	.000	101.781	6.333
	23	1	1	.068	1	1.000	3.331	2	.000	98.173	6.152
	25	1	1	.393	1	1.000	.731	2	.000	79.892	5.182
	26	1	1	.244	1	1.000	1.360	2	.000	85.554	5.494
	27	1	1	.016	1	1.000	5.831	2	.000	110.210	6.742
	28	1	1	.053	1	1.000	3.737	2	.000	100.328	6.261
	29	1	1	.679	1	1.000	.172	2	.000	58.811	3.913
	30	1	1	.928	1	1.000	.008	2	.000	63.880	4.237
	31	1	1	.857	1	1.000	.033	2	.000	62.452	4.147
	32	1	1	.651	1	1.000	.204	2	.000	58.235	3.875
	33	1	1	.962	1	1.000	.002	2	.000	66.117	4.375
	37	1	1	.063	1	1.000	3.457	2	.000	98.855	6.187
	38	1	1	.697	1	1.000	.152	2	.000	59.196	3.938
	39	1	1	.323	1	1.000	.978	2	.000	50.326	3.338
	40	1	1	.329	1	1.000	.953	2	.000	50.507	3.351
	41	1	1	.652	1	1.000	.203	2	.000	72.825	4.778
	42	1	1	.198	1	1.000	1.661	2	.000	87.834	5.616

	43	1	1	.983	1	1.000	.000	2	.000	64.992	4.306
	44	1	1	.902	1	1.000	.015	2	.000	63.360	4.204
	45	1	1	.042	1	1.000	4.126	2	.000	102.302	6.359
	46	1	1	.442	1	1.000	.590	2	.000	53.510	3.559
	48	1	1	.558	1	1.000	.343	2	.000	75.145	4.913
	49	1	1	.643	1	1.000	.215	2	.000	58.063	3.864
	50	1	1	.273	1	1.000	1.201	2	.000	84.256	5.423
	51	1	1	.791	1	1.000	.070	2	.000	69.687	4.592
	52	1	1	.318	1	1.000	.997	2	.000	82.477	5.326
	53	1	1	.177	1	1.000	1.826	2	.000	89.009	5.679
	54	1	1	.998	1	1.000	.000	2	.000	65.305	4.325
	55	1	1	.271	1	1.000	1.212	2	.000	48.754	3.227
	56	1	1	.544	1	1.000	.368	2	.000	55.905	3.721
	57	1	1	.743	1	1.000	.108	2	.000	60.140	3.999
	58	1	1	.121	1	1.000	2.407	2	.000	42.666	2.776
	59	1	1	.021	1	1.000	5.330	2	.000	33.346	2.019
	60	1	1	.020	1	1.000	5.371	2	.000	33.244	2.010
	61	1	1	.172	1	1.000	1.865	2	.000	45.127	2.962
	62	1	1	.393	1	1.000	.730	2	.000	79.887	5.182
	63	1	1	.734	1	1.000	.115	2	.000	59.961	3.988
	64	1	1	.029	1	1.000	4.759	2	.000	34.831	2.146
	65	1	1	.058	1	1.000	3.602	2	.000	38.259	2.430
	66	2	2	.508	1	1.000	.438	1	.000	76.483	-4.418
	67	2	2	.749	1	1.000	.103	1	.000	70.622	-4.076
	68	2	2	.933	1	1.000	.007	1	.000	66.698	-3.839

	69	2	2	.572	1	1.000	.319	1	.000	74.787	-4.321
	70	2	2	.600	1	1.000	.275	1	.000	57.135	-3.231
	72	2	2	.690	1	1.000	.160	1	.000	71.955	-4.155
	73	2	2	.649	1	1.000	.207	1	.000	72.901	-4.211
	74	2	2	.888	1	1.000	.020	1	.000	67.639	-3.897
	75	2	2	.860	1	1.000	.031	1	.000	62.528	-3.580
	76	2	2	.267	1	1.000	1.230	1	.000	84.500	-4.865
	77	2	2	.340	1	1.000	.910	1	.000	81.671	-4.710
	78	2	2	.586	1	1.000	.297	1	.000	74.449	-4.301
	81	2	2	.443	1	1.000	.589	1	.000	53.517	-2.988
	82	2	2	.791	1	1.000	.070	1	.000	61.118	-3.490
	83	2	2	.392	1	1.000	.734	1	.000	52.226	-2.899
	84	2	2	.511	1	1.000	.432	1	.000	55.143	-3.098
	85	2	2	.820	1	1.000	.052	1	.000	69.060	-3.983
	86	2	2	.683	1	1.000	.167	1	.000	58.894	-3.347
	90	2	2	.773	1	1.000	.084	1	.000	60.750	-3.467
	92	2	2	.892	1	1.000	.018	1	.000	63.161	-3.620
	93	2	2	.996	1	1.000	.000	1	.000	65.415	-3.761
	94	2	2	.843	1	1.000	.039	1	.000	62.175	-3.558
	95	2	2	.618	1	1.000	.249	1	.000	73.657	-4.255
	96	2	2	.910	1	1.000	.013	1	.000	67.179	-3.869
	99	2	2	.744	1	1.000	.107	1	.000	60.156	-3.429
	100	2	2	.286	1	1.000	1.137	1	.000	83.712	-4.822
	101	2	2	.971	1	1.000	.001	1	.000	65.922	-3.792
	102	2	2	.737	1	1.000	.112	1	.000	70.873	-4.091

	103	2	2	.783	1	1.000	.076	1	.000	69.867	-4.031
	104	2	2	.965	1	1.000	.002	1	.000	64.626	-3.712
	105	2	2	.484	1	1.000	.489	1	.000	54.525	-3.057
	106	2	2	.283	1	1.000	1.152	1	.000	49.142	-2.683
	107	2	2	.320	1	1.000	.988	1	.000	50.255	-2.762
	108	2	2	.076	1	1.000	3.158	1	.000	39.767	-1.979
	109	2	2	.167	1	1.000	1.914	1	.000	44.887	-2.372
	110	2	2	.072	1	1.000	3.234	1	.000	39.501	-1.958
	111	2	2	.354	1	1.000	.858	1	.000	51.221	-2.829
	112	2	2	.591	1	1.000	.289	1	.000	56.938	-3.218
	113	2	2	.717	1	1.000	.131	1	.000	59.609	-3.393
	114	2	2	.288	1	1.000	1.128	1	.000	49.298	-2.694
	115	2	2	.217	1	1.000	1.525	1	.000	46.903	-2.521
	116	2	2	.409	1	1.000	.681	1	.000	52.682	-2.931
	118	2	2	.837	1	1.000	.043	1	.000	68.716	-3.962
	125	2	2	.910	1	1.000	.013	1	.000	67.182	-3.869
	127	2	2	.266	1	1.000	1.235	1	.000	84.538	-4.867
	128	2	2	.313	1	1.000	1.018	1	.000	82.668	-4.765
	130	2	2	.249	1	1.000	1.329	1	.000	85.309	-4.909
	131	2	2	.270	1	1.000	1.217	1	.000	84.394	-4.859
	132	2	2	.634	1	1.000	.227	1	.000	73.272	-4.232
	133	2	2	.628	1	1.000	.235	1	.000	73.414	-4.241
	139	2	2	.118	1	1.000	2.438	1	.000	93.019	-5.317
	141	2	2	.252	1	1.000	1.315	1	.000	85.190	-4.902
	143	2	2	.419	1	1.000	.654	1	.000	79.069	-4.565

	148	2	2	.473	1	1.000	.515	1	.000	77.456	-4.474
	149	2	2	.282	1	1.000	1.157	1	.000	83.889	-4.832
	151	2	2	.259	1	1.000	1.274	1	.000	84.864	-4.885
	153	2	2	.495	1	1.000	.465	1	.000	76.826	-4.438
	154	2	2	.829	1	1.000	.047	1	.000	68.882	-3.972
	155	2	2	.442	1	1.000	.591	1	.000	78.360	-4.525
	156	2	2	.596	1	1.000	.282	1	.000	74.201	-4.287
	157	2	2	.495	1	1.000	.465	1	.000	76.825	-4.438
	158	2	2	.696	1	1.000	.152	1	.000	59.185	-3.366

Table H.5 DFA stepwise statistics of Niton quarry sample compositions.

Variables Entered/Removed[a,b,c,d]										
Step	Entered	Removed	Wilks' Lambda							
			Statistic	df1	df2	df3	Exact F			
							Statistic	df1	df2	Sig.
1	CaO		0.116	1	1	97.000	735.678	1	97.000	0.000
2	TiO2		0.080	2	1	97.000	550.227	2	96.000	0.000
3	Zn		0.071	3	1	97.000	414.701	3	95.000	0.000
4	FeO		0.063	4	1	97.000	349.541	4	94.000	0.000
5	Zr		0.059	5	1	97.000	298.037	5	93.000	0.000
6		TiO2	0.060	4	1	97.000	369.060	4	94.000	0.000
7	MnO		0.057	5	1	97.000	308.541	5	93.000	0.000
At each step, the variable that minimizes the overall Wilks' Lambda is entered.										
a. Maximum number of steps is 24.										
b. Minimum partial F to enter is 3.84.										
c. Maximum partial F to remove is 2.71.										
d. F level, tolerance, or VIN insufficient for further computation.										

Table H.6 DFA stepwise statistics of the Niton quarry compositions for variables in analysis.

Variables in the Analysis				
Step		Tolerance	F to Remove	Wilks' Lambda
1	CaO	1.000	735.678	
2	CaO	1.000	144.437	0.201
	TiO2	1.000	43.377	0.116
3	CaO	0.987	132.289	0.170
	TiO2	1.000	36.881	0.098
	Zn	0.987	12.446	0.080
4	CaO	0.986	107.160	0.135
	TiO2	0.762	7.489	0.068
	Zn	0.825	21.170	0.077
	FeO	0.660	11.859	0.071
5	CaO	0.980	80.977	0.110
	TiO2	0.640	1.775	0.060
	Zn	0.825	19.477	0.071
	FeO	0.598	16.400	0.069
	Zr	0.815	6.734	0.063
6	CaO	0.980	84.178	0.113
	Zn	0.851	24.035	0.075
	FeO	0.855	42.452	0.087
	Zr	0.969	12.799	0.068
7	CaO	0.978	79.778	0.106
	Zn	0.838	18.680	0.068
	FeO	0.801	47.772	0.086
	Zr	0.967	11.169	0.064
	MnO	0.881	4.919	0.060

Table H.7 DFA stepwise statistics of the Niton quarry compositions for variables not in analysis.

Variables Not in the Analysis					
Step		Tolerance	Min. Tolerance	F to Enter	Wilks' Lambda
0	Zr	1.000	1.000	215.958	0.310
	Sr	1.000	1.000	102.902	0.485
	Rb	1.000	1.000	0.089	0.999
	Zn	1.000	1.000	83.835	0.536
	FeO	1.000	1.000	240.904	0.287
	MnO	1.000	1.000	26.444	0.786
	BaO	1.000	1.000	145.529	0.400
	Nb	1.000	1.000	151.798	0.390
	Cr2O3	1.000	1.000	17.513	0.847
	TiO2	1.000	1.000	385.688	0.201
	CaO	1.000	1.000	735.678	0.116
	K2O	1.000	1.000	5.573	0.946
1	Zr	0.995	0.995	18.956	0.097
	Sr	0.932	0.932	1.158	0.115
	Rb	0.973	0.973	2.055	0.114
	Zn	0.987	0.987	17.553	0.098
	FeO	1.000	1.000	26.095	0.092
	MnO	0.996	0.996	5.307	0.110
	BaO	1.000	1.000	15.887	0.100
	Nb	0.999	0.999	19.807	0.097
	Cr2O3	0.992	0.992	0.337	0.116
	TiO2	1.000	1.000	43.377	0.080
	K2O	0.989	0.989	3.198	0.113
2	Zr	0.913	0.913	4.506	0.077

	Sr	0.910	0.910	2.997	0.078
	Rb	0.909	0.909	0.045	0.080
	Zn	0.987	0.987	12.446	0.071
	FeO	0.789	0.789	3.759	0.077
	MnO	0.985	0.985	1.754	0.079
	BaO	0.814	0.814	1.104	0.079
	Nb	0.929	0.929	5.366	0.076
	Cr2O3	0.988	0.988	0.621	0.080
	K2O	0.948	0.948	0.146	0.080
3	Zr	0.899	0.899	2.506	0.069
	Sr	0.907	0.907	2.048	0.069
	Rb	0.905	0.905	0.179	0.071
	FeO	0.660	0.660	11.859	0.063
	MnO	0.933	0.933	0.245	0.071
	BaO	0.813	0.813	1.190	0.070
	Nb	0.897	0.897	2.511	0.069
	Cr2O3	0.960	0.958	1.735	0.070
	K2O	0.946	0.946	0.043	0.071
4	Zr	0.815	0.598	6.734	0.059
	Sr	0.904	0.657	2.418	0.061
	Rb	0.848	0.619	0.181	0.063
	MnO	0.811	0.574	3.057	0.061
	BaO	0.813	0.653	0.925	0.062
	Nb	0.852	0.626	5.158	0.060
	Cr2O3	0.941	0.647	0.624	0.063
	K2O	0.900	0.627	0.874	0.062
5	Sr	0.811	0.597	0.542	0.058
	Rb	0.848	0.564	0.158	0.059

	MnO	0.806	0.518	3.552	0.057
	BaO	0.808	0.549	1.284	0.058
	Nb	0.258	0.247	0.033	0.059
	Cr2O3	0.941	0.588	0.624	0.058
	K2O	0.899	0.571	0.855	0.058
6	Sr	0.855	0.846	0.181	0.060
	Rb	0.943	0.851	0.646	0.059
	MnO	0.881	0.801	4.919	0.057
	BaO	0.942	0.809	2.459	0.058
	Nb	0.258	0.258	0.036	0.060
	Cr2O3	0.952	0.839	0.430	0.060
	TiO2	0.640	0.598	1.775	0.059
	K2O	0.968	0.850	1.587	0.059
7	Sr	0.841	0.786	0.482	0.057
	Rb	0.943	0.797	0.616	0.056
	BaO	0.678	0.634	0.203	0.057
	Nb	0.235	0.235	0.226	0.057
	Cr2O3	0.920	0.787	0.061	0.057
	TiO2	0.586	0.518	0.484	0.057
	K2O	0.957	0.792	2.127	0.056

Table H.8 DFA stepwise Wilks' Lambda of the Niton quarry compositions groups.

Wilks' Lambda									
Step	Number of Variables	Lambda	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	1	0.116	1	1	97	735.678	1	97.000	0.000
2	2	0.080	2	1	97	550.227	2	96.000	0.000
3	3	0.071	3	1	97	414.701	3	95.000	0.000
4	4	0.063	4	1	97	349.541	4	94.000	0.000
5	5	0.059	5	1	97	298.037	5	93.000	0.000
6	4	0.060	4	1	97	369.060	4	94.000	0.000
7	5	0.057	5	1	97	308.541	5	93.000	0.000

Appendix I

DFA Results for 25% Holdout Sample of Quarry Samples Analyzed on the Niton

Table I.1 DFA group statistics of Niton compositions of quarry samples 25% holdout.

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	14.451[a]	100.0	100.0	.967
a. First 1 canonical discriminant functions were used in the analysis.				

Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.065	188.900	4	.000

Table I.2 Standardized canonical discriminant function coefficients for groups of Niton compositions of quarry samples with a 25% holdout.

Standardized Canonical Discriminant Function Coefficients	
	Function
	1
Zr	.426
Zn	-.510
FeO	.606
CaO	.671

Table I.3 Predicted group membership of 25% holdout of quarry samples analyzed on the Niton.

		Quarry	Predicted Group Membership		Total
			Landmark Gap	Long Tangle Lake	
Original	Count	Landmark Gap	40	0	40
		Long Tangle Lake	0	50	50
	%	Landmark Gap	100.0	.0	100.0
		Long Tangle Lake	.0	100.0	100.0
a. 100.0% of original grouped cases correctly classified.					

Table I.4 Descriptive statistics and equality of group means of 25% holdout Niton quarry group compositions.

Quarry		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Landmark Gap Quarry	Zr	140.81	32.28	34	34
	Sr	348.75	106.89	34	34
	Rb	25.91	21.58	34	34
	Zn	35.84	6.01	34	34
	FeO	2.88	0.36	34	34
	MnO	0.04	0.01	34	34
	BaO	1294.71	716.88	34	34
	Nb	16.11	4.06	34	34
	Cr2O3	88.14	10.61	34	34
	TiO2	0.17	0.02	34	34
	CaO	0.93	0.24	34	34
	K2O	0.56	0.41	34	34
Long Tangle Lake Quarry	Zr	71.88	8.86	39	39
	Sr	182.47	56.20	39	39
	Rb	26.86	4.94	39	39
	Zn	55.00	14.44	39	39
	FeO	1.60	0.43	39	39
	MnO	0.06	0.03	39	39
	BaO	5039.12	1961.16	39	39
	Nb	9.02	1.64	39	39
	Cr2O3	97.57	14.23	39	39
	TiO2	0.09	0.02	39	39

	CaO	0.09	0.03	39	39
	K2O	0.46	0.08	39	39
Total	Zr	103.99	41.44	73	73
	Sr	259.92	117.81	73	73
	Rb	26.42	15.05	73	73
	Zn	46.08	14.81	73	73
	FeO	2.20	0.75	73	73
	MnO	0.05	0.03	73	73
	BaO	3295.15	2408.86	73	73
	Nb	12.32	4.65	73	73
	Cr2O3	93.18	13.45	73	73
	TiO2	0.13	0.05	73	73
	CaO	0.48	0.45	73	73
	K2O	0.56	0.29	73	73

Table I.5 DFA stepwise statistics of 25% holdout of Niton quarry sample compositions.

Variables Entered/Removed[a,b,c,d]										
			Wilks' Lambda							
							Exact F			
Step	Entered	Removed	Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	CaO		.129	1	1	71.000	477.602	1	71.000	.000
2	TiO2		.081	2	1	71.000	397.094	2	70.000	.000
3	Zn		.074	3	1	71.000	288.199	3	69.000	.000
4	FeO		.069	4	1	71.000	231.083	4	68.000	.000
5	Zr		.062	5	1	71.000	201.008	5	67.000	.000
6		TiO2	.065	4	1	71.000	245.668	4	68.000	.000

At each step, the variable that minimizes the overall Wilks' Lambda is entered.

a. Maximum number of steps is 24.

b. Minimum partial F to enter is 3.84.

c. Maximum partial F to remove is 2.71.

d. F level, tolerance, or VIN insufficient for further computation.

Table I.6 DFA stepwise statistics of the 25% holdout of Niton quarry compositions for variables in analysis.

Variables in the Analysis				
Step		Tolerance	F to Remove	Wilks' Lambda
1	CaO	1.000	477.602	
2	CaO	.998	98.146	.195
	TiO2	.998	41.843	.129
3	CaO	.985	93.661	.174
	TiO2	.997	33.805	.110
	Zn	.985	6.622	.081
4	CaO	.969	61.917	.131
	TiO2	.747	9.064	.078
	Zn	.756	11.463	.080
	FeO	.608	5.341	.074
5	CaO	.967	48.119	.107
	TiO2	.633	2.383	.065
	Zn	.755	10.829	.073

	FeO	.562	8.155	.070
	Zr	.830	6.462	.069
6	CaO	.978	47.578	.110
	Zn	.810	16.708	.081
	FeO	.806	25.997	.089
	Zr	.980	13.594	.078

Table I.7 DFA stepwise statistics of the 25% holdout of Niton quarry compositions for variables not in analysis.

Variables Not in the Analysis					
Step		Tolerance	Min. Tolerance	F to Enter	Wilks' Lambda
0	Zr	1.000	1.000	164.005	.302
	Sr	1.000	1.000	71.737	.497
	Rb	1.000	1.000	.072	.999
	Zn	1.000	1.000	51.977	.577
	FeO	1.000	1.000	184.856	.277
	MnO	1.000	1.000	20.886	.773
	BaO	1.000	1.000	110.856	.390
	Nb	1.000	1.000	100.686	.414
	Cr2O3	1.000	1.000	10.037	.876
	TiO2	1.000	1.000	293.906	.195
	CaO	1.000	1.000	477.602	.129
	K2O	1.000	1.000	2.548	.965
1	Zr	1.000	1.000	22.461	.098
	Sr	.931	.931	1.019	.128
	Rb	.909	.909	5.604	.120
	Zn	.987	.987	12.271	.110
	FeO	.983	.983	14.932	.107
	MnO	.994	.994	4.986	.121
	BaO	.996	.996	10.535	.112
	Nb	.997	.997	16.380	.105
	Cr2O3	.977	.977	.002	.129
	TiO2	.998	.998	41.843	.081
	K2O	.942	.942	6.363	.119
2	Zr	.909	.908	5.296	.075
	Sr	.929	.929	1.022	.080

	Rb	.874	.874	.765	.080
	Zn	.985	.985	6.622	.074
	FeO	.793	.793	.796	.080
	MnO	.897	.897	.030	.081
	BaO	.785	.785	.058	.081
	Nb	.907	.907	3.025	.078
	Cr2O3	.977	.976	.002	.081
	K2O	.922	.922	1.551	.079
3	Zr	.898	.898	3.689	.070
	Sr	.922	.913	.549	.073
	Rb	.869	.869	.420	.073
	FeO	.608	.608	5.341	.069
	MnO	.854	.854	.142	.074
	BaO	.783	.783	.134	.074
	Nb	.879	.879	1.529	.072
	Cr2O3	.933	.933	.331	.074
	K2O	.919	.919	1.097	.073
4	Zr	.830	.562	6.462	.062
	Sr	.921	.608	.440	.068
	Rb	.854	.597	.844	.068
	MnO	.763	.543	.144	.068
	BaO	.765	.583	.471	.068
	Nb	.834	.577	2.989	.066
	Cr2O3	.931	.607	.207	.068
	K2O	.908	.601	1.558	.067
5	Sr	.759	.550	.178	.062
	Rb	.843	.548	1.318	.061
	MnO	.760	.500	.282	.062
	BaO	.762	.500	.665	.062
	Nb	.228	.227	.626	.062
	Cr2O3	.927	.562	.340	.062
	K2O	.888	.550	2.428	.060
6	Sr	.800	.800	.592	.064
	Rb	.903	.806	2.356	.063
	MnO	.924	.792	1.310	.063
	BaO	.965	.793	2.104	.063
	Nb	.229	.229	.525	.064

	Cr2O3	.927	.784	.355	.064
	TiO2	.633	.562	2.383	.062
	K2O	.934	.806	3.618	.061

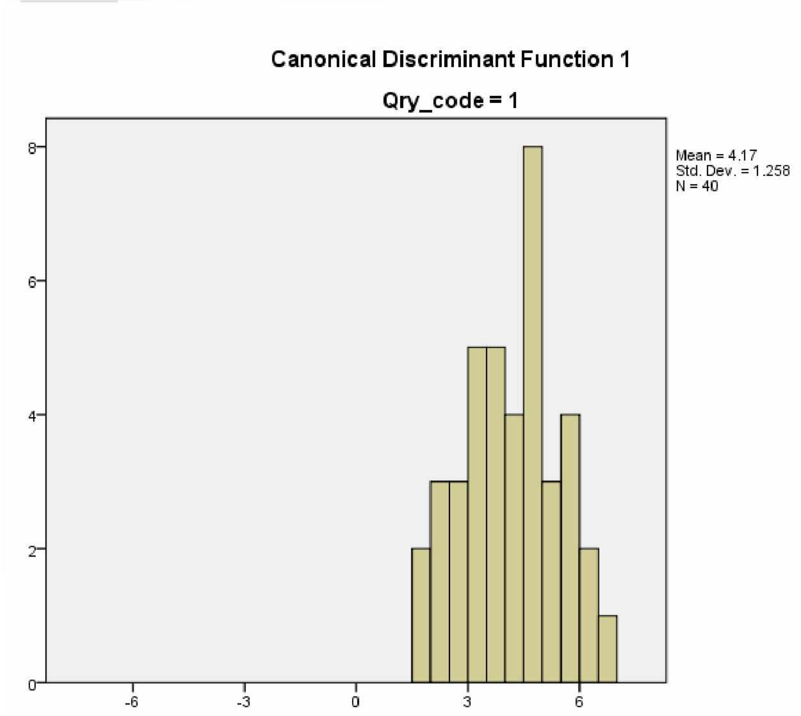

Figure I.1 Landmark Gap Quarry 25% holdout Niton compositional group function.

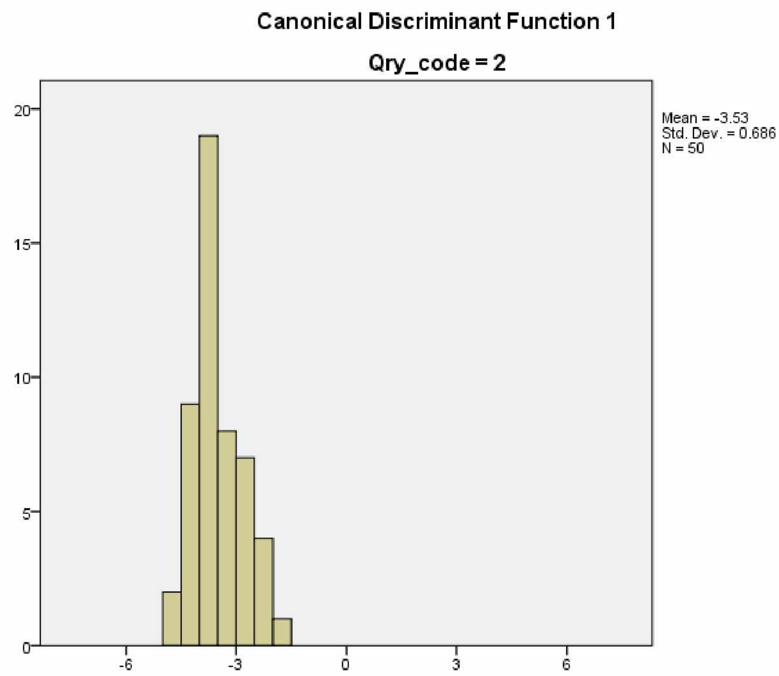

Figure I.2 Long Tangle Lake Quarry 25% holdout Niton compositional group function.

Based on the 25% holdout sample one less element was used to predict the groups, such that MnO was excluded. Therefore, a stepwise DFA of the Niton data of the quarry samples and artifacts was performed with Zr, Zn, FeO, and CaO, excluding MnO. There were no clear benefits based on this DFA for excluding MnO.

Appendix J

Niton Compositional Data for all Quarry Samples and Artifact Analyses

Table J.1 Complete compositional data collected on the Niton for quarry samples and artifacts.

Sample	Zr	Sr	Rb	Zn	FeO	MnO	BaO	Nb	Cr_2O_3	TiO_2	CaO	K_2O	S
UA2012-059-612 AVERAGE	223.98	416.81	26.69	66.66	2.69	0.08	1899.78	41.68	141.11	0.25	1.30	0.99	0.00
UA2012-059-608 AVERAGE	72.28	108.27	18.07	39.53	1.16	0.05	4422.88	42.47	173.48	0.01	0.32	0.34	0.00
UA2012-059-591 AVERAGE	77.93	263.86	23.11	64.32	1.58	0.03	7515.85	17.26	112.74	0.07	0.34	0.40	0.00
UA2012-059-606 AVERAGE	80.89	281.46	30.28	77.11	2.15	0.06	9353.54	11.50	103.86	0.11	0.20	0.53	816.72
UA2012-059-603 AVERAGE	88.11	266.34	24.36	68.87	2.22	0.04	6499.94	21.70	118.54	0.08	0.26	0.33	219.22
UA2012-059-602 AVERAGE	74.81	169.61	10.69	46.76	1.27	0.10	10014.49	17.31	122.32	0.04	0.15	0.21	480.32
UA2012-059-614 AVERAGE	84.39	254.70	22.21	69.55	2.24	0.05	6637.83	18.26	115.35	0.08	0.24	0.36	214.80
UA2012-059-638 AVERAGE	111.39	411.91	30.24	115.81	2.79	0.11	5790.91	41.28	139.83	0.09	0.22	0.35	523.56
UA2012-059-627 AVERAGE	142.30	996.26	48.08	134.70	1.93	0.23	19920.55	41.94	207.16	0.07	0.35	0.71	0.00
UA2012-059-598 AVERAGE	142.19	206.08	83.69	43.72	1.07	0.02	6324.52	62.14	298.03	0.10	0.33	1.52	0.00
UA2012-059-588 AVERAGE	166.48	233.32	110.43	21.81	0.15	0.01	1701.47	46.48	109.31	0.12	0.51	5.40	208.83
UA2012-059-586 AVERAGE	145.01	317.16	28.10	51.68	2.99	0.05	2132.64	35.27	148.63	0.19	1.25	1.23	0.00
UA2012-059-632 AVERAGE	74.29	231.61	24.61	65.49	1.57	0.04	6491.49	13.84	113.15	0.07	0.22	0.37	0.00
UA2012-059-585 AVERAGE	80.97	193.60	29.88	58.55	1.43	0.03	5663.10	15.36	100.18	0.09	0.25	0.43	320.46
UA2012-059-584 AVERAGE	91.38	22.21	46.73	28.77	0.32	0.01	238.56	18.60	94.27	0.10	0.40	0.59	228.78
UA2012-059-628 AVERAGE	85.91	66.49	35.44	55.64	1.70	0.11	301.36	54.66	121.11	0.11	0.22	0.56	546.89
UA2012-059-640 AVERAGE	45.73	92.35	24.69	45.20	0.93	0.04	13490.23	10.54	206.86	0.00	0.17	0.77	287.36
UA2012-059-645 AVERAGE	98.00	527.89	30.23	88.22	1.59	0.11	20131.01	19.21	132.81	0.06	0.27	0.57	228.72
UA2012-059-646 AVERAGE	69.99	47.96	40.58	22.52	0.25	0.01	1153.76	33.75	131.59	0.11	0.27	0.87	0.00

UA2012-059-671-3 AVERAGE	119.83	262.71	21.91	51.85	1.61	0.09	12308.35	31.46	247.46	0.05	0.27	0.60	0.00
UA2012-059-671-1 AVERAGE	80.63	61.96	53.36	46.82	1.25	0.01	2210.14	46.44	190.74	0.04	0.18	0.96	262.64
UA2012-059-671-6 AVERAGE	91.41	33.49	13.77	33.07	1.39	0.14	41.41	34.60	50.51	0.06	0.24	0.25	216.80
UA2012-059-671-2 AVERAGE	63.84	77.94	14.20	35.92	0.54	0.04	8394.24	14.23	170.43	0.03	0.29	0.47	0.00
UA2012-059-671-8 AVERAGE	96.59	144.66	67.23	37.80	1.38	0.02	6296.58	47.63	247.70	0.07	0.34	1.23	0.00
UA2012-059-671-11 AVERAGE	71.48	70.12	22.41	91.89	2.35	0.04	2083.67	39.70	148.88	0.08	0.31	0.65	0.00
UA2012-059-662 AVERAGE	142.37	331.50	19.44	47.09	1.79	0.06	7275.35	37.07	188.73	0.17	0.35	0.47	0.00
UA2012-059-660 AVERAGE	58.06	66.18	30.13	27.65	0.33	0.00	2683.78	34.39	134.54	0.05	0.22	0.58	0.00
UA2012-059-670-1 AVERAGE	117.99	198.50	7.51	118.26	7.18	0.10	318.54	15.76	108.65	0.53	5.94	0.12	0.00
UA2012-059-670-2 AVERAGE	126.82	154.42	56.65	27.45	0.24	0.03	16361.91	43.60	322.82	0.13	0.82	1.28	0.00
UA2012-059-670-3 AVERAGE	243.60	373.24	28.24	140.82	4.59	0.14	452.80	26.68	49.90	0.44	3.42	0.82	0.00
UA2012-059-670-4 AVERAGE	279.37	450.99	39.66	153.31	5.05	0.14	302.31	35.72	57.26	0.42	3.45	1.13	0.00
UA2012-059-668 AVERAGE	87.24	85.90	43.19	65.79	1.00	0.02	480.49	33.14	103.12	0.09	0.36	0.60	242.87
UA2012-059-669-4 AVERAGE	110.55	353.15	34.28	91.90	2.31	0.04	8103.17	39.05	170.67	0.09	0.29	0.51	0.00
UA2012-059-669-3 AVERAGE	132.87	557.25	44.23	118.36	2.43	0.10	6022.83	52.02	156.82	0.11	0.27	0.54	196.72
UA2012-059-669-5 AVERAGE	103.39	281.07	27.52	87.47	2.40	0.05	6280.84	36.66	145.47	0.08	0.26	0.38	231.78
UA2012-059-669-8 AVERAGE	106.41	298.02	31.64	96.32	2.89	0.06	7247.42	29.80	135.75	0.11	0.52	0.53	0.00
UA2012-059-669-12 AVERAGE	94.62	343.52	25.18	84.11	1.81	0.04	9560.86	25.66	143.75	0.08	0.21	0.43	0.00
UA2012-059-669-13 AVERAGE	114.97	258.65	34.04	66.51	1.87	0.05	6677.69	44.14	148.85	0.12	0.22	0.51	0.00
UA2012-059-669-15 AVERAGE	56.01	53.86	13.57	24.32	0.94	0.08	829.15	44.81	107.93	0.03	0.26	0.20	0.00
UA2012-059-669-18 AVERAGE	429.94	537.19	60.68	162.58	4.74	0.14	436.11	54.33	49.94	0.41	2.91	1.48	0.00
UA2012-059-669-21 AVERAGE	305.04	417.98	176.17	176.44	6.59	0.06	349.84	57.21	178.82	0.44	0.98	2.79	0.00
UA2012-059-669-26 AVERAGE	122.55	127.64	19.62	46.07	1.13	0.03	965.52	49.63	142.59	0.13	0.93	0.70	0.00
UA2012-059-669-40 AVERAGE	65.38	109.21	17.78	38.04	0.51	0.04	7529.90	26.58	135.17	0.03	0.25	0.27	0.00

UA2012-059-669-42 AVERAGE	78.18	92.80	14.20	50.07	1.84	0.11	5884.84	16.07	93.64	0.05	0.15	0.25	0.00
UA2012-059-669-43 AVERAGE	162.51	587.33	36.57	61.92	1.68	0.22	17179.46	42.30	357.01	0.07	0.23	0.75	0.00
UA2012-059-669-44 AVERAGE	187.55	332.49	48.55	50.58	1.41	0.07	19663.37	47.27	343.61	0.24	0.34	1.02	0.00
UA2012-059-669-48 AVERAGE	199.30	527.58	38.96	79.21	1.69	0.20	14552.37	59.35	407.85	0.13	0.45	0.89	312.94
UA2012-059-669-51 AVERAGE	148.48	609.14	48.53	94.77	2.00	0.13	18721.80	34.21	143.72	0.12	0.33	0.78	0.00
UA2012-059-669-51 AVERAGE	87.90	113.01	18.00	56.41	1.89	0.08	7665.77	31.65	181.46	0.03	0.16	0.36	163.58
UA2012-059-669-55 AVERAGE	89.67	156.65	26.90	60.71	1.59	0.07	11127.26	30.93	233.11	0.00	0.32	0.59	0.00
UA2012-059-669-63 AVERAGE	101.81	346.13	27.20	69.45	3.50	0.11	455.44	48.33	132.44	0.20	1.03	0.58	0.00
UA2012-059-669-65 AVERAGE	165.00	200.45	132.45	45.05	1.50	0.03	1979.54	52.19	122.35	0.11	0.82	6.34	0.00
UA2012-059-669-67 AVERAGE	146.68	817.27	51.34	110.09	2.10	0.18	19661.50	40.08	165.96	0.08	0.32	1.13	511.41
UA2012-059-669-76 AVERAGE	308.61	556.83	107.14	89.92	4.80	0.15	2736.14	65.53	182.63	0.17	1.29	2.15	1250.52
UA2012-059-669-77 AVERAGE	328.84	747.36	134.68	260.58	5.99	0.23	2593.94	84.97	227.78	0.31	1.60	4.18	0.00
UA2012-059-669-79 AVERAGE	106.12	159.63	13.97	76.00	2.11	0.04	0.00	43.96	104.33	0.14	0.58	0.42	0.00
UA2012-059-669-81 AVERAGE	77.08	97.95	15.25	40.58	1.61	0.02	222.49	28.66	59.61	0.11	0.21	0.36	229.77
UA2012-059-669-83 AVERAGE	123.04	347.91	33.25	50.04	2.88	0.07	635.46	42.90	128.53	0.24	0.93	0.57	0.00
UA2012-059-669-90 AVERAGE	130.54	199.16	48.57	74.65	2.46	0.06	423.32	36.58	94.68	0.17	2.08	1.59	290.01
UA2012-059-669-91 AVERAGE	117.09	301.79	38.95	137.65	2.41	0.06	8109.27	45.66	230.58	0.07	0.32	1.90	229.15
UA2012-059-669-104 AVERAGE	129.63	552.59	45.74	62.40	2.17	0.04	2131.24	48.73	137.86	0.20	2.30	1.15	0.00
UA2012-059-669-115 AVERAGE	95.93	227.82	27.92	80.11	3.03	0.06	5708.32	24.95	110.42	0.10	0.24	0.51	0.00
UA2012-059-669-117 AVERAGE	90.27	286.99	27.80	73.48	1.85	0.05	8167.45	16.90	103.71	0.08	0.24	0.47	0.00
UA2012-059-669-116 AVERAGE	101.76	199.60	33.15	77.93	2.77	0.05	5139.39	24.40	126.33	0.10	0.35	0.55	0.00
UA2012-059-669-119 AVERAGE	79.05	224.18	29.08	53.67	1.29	0.03	6515.22	10.20	101.49	0.08	0.21	0.53	0.00
UA2012-059-669-120 AVERAGE	109.99	298.44	36.24	71.88	1.98	0.06	6532.17	40.73	140.37	0.09	0.29	0.53	0.00
UA2012-059-669-129 AVERAGE	110.06	425.44	23.07	105.76	1.64	0.31	14269.28	36.47	295.73	0.00	0.24	0.53	0.00

UA2012-059-669-138 AVERAGE	66.16	50.60	39.59	21.21	1.03	0.00	2404.56	51.06	183.48	0.05	0.21	0.58	0.00
UA2012-059-669-142 AVERAGE	170.59	715.65	47.31	94.83	4.28	0.08	340.96	29.98	41.26	0.30	3.56	1.27	0.00
UA2012-059-669-143 AVERAGE	289.69	393.69	180.03	235.93	6.58	0.04	557.26	53.81	190.14	0.43	0.87	2.84	383.78
UA2012-059-669-153 AVERAGE	142.70	129.44	41.26	63.22	1.45	0.03	4495.19	67.71	262.56	0.11	0.24	1.11	0.00
UA2012-059-669-155 AVERAGE	259.00	610.87	78.11	213.76	4.08	0.11	3255.92	58.27	217.86	0.23	1.26	2.55	0.00
UA2012-059-669-156 AVERAGE	142.63	298.01	34.29	15.94	0.09	0.00	370.50	60.35	77.15	0.10	0.61	1.65	0.00
UA2012-059-669-160 AVERAGE	101.61	278.49	36.00	64.28	2.08	0.06	7353.63	25.22	115.05	0.11	0.21	0.58	0.00
UA2012-059-669-166 AVERAGE	122.45	172.85	71.72	23.70	0.32	0.01	662.89	46.59	102.31	0.16	0.91	3.66	0.00
UA2012-059-669-171 AVERAGE	388.68	1100.31	33.54	92.06	4.12	0.13	297.30	74.45	130.10	0.30	3.39	0.45	0.00
UA2012-059-669-172 AVERAGE	122.97	240.74	48.94	32.81	0.97	0.03	613.10	43.12	105.69	0.11	0.71	2.05	0.00
UA2012-059-669-174 AVERAGE	110.78	442.14	4.81	39.67	2.42	0.05	45.17	31.38	109.08	0.18	2.45	0.10	0.00
UA2012-059-986-2 AVERAGE	36.32	45.12	8.51	12.38	0.28	0.02	1889.15	20.25	94.76	0.00	0.13	0.15	0.00
UA2012-059-986-3 AVERAGE	42.73	71.50	12.66	30.90	1.02	0.04	4553.82	19.07	111.78	0.01	0.18	0.23	0.00
UA2012-059-986-5 AVERAGE	101.91	160.13	20.20	52.89	1.61	0.10	8214.21	41.67	211.14	0.02	0.14	0.33	513.23
UA2012-059-986-10 AVERAGE	74.27	67.61	15.26	45.91	2.03	0.17	831.43	51.73	131.62	0.05	0.25	0.19	0.00
UA2012-059-986-13 AVERAGE	43.73	111.28	15.54	24.70	0.38	0.04	17430.64	2.51	212.10	0.00	0.14	0.56	0.00
UA2012-059-986-14 AVERAGE	64.24	119.92	21.97	37.03	1.24	0.06	15165.31	16.30	203.01	0.00	0.14	0.42	0.00
UA2012-059-986-15 AVERAGE	65.79	148.83	15.37	25.31	1.04	0.06	8055.47	24.36	151.27	0.07	0.24	0.26	0.00
UA2012-059-986-16 AVERAGE	103.93	157.84	23.39	38.91	1.66	0.08	12186.46	36.03	218.24	0.03	0.17	0.41	202.99
UA2012-059-986-17 AVERAGE	115.53	226.42	23.08	39.22	1.53	0.08	13947.58	31.56	252.89	0.02	0.34	0.51	0.00
UA2012-059-986-23 AVERAGE	83.64	44.56	21.12	8.43	0.23	0.00	44.65	32.43	115.88	0.06	0.25	0.52	0.00
UA2012-059-986-26 AVERAGE	102.30	121.44	24.31	38.23	2.06	0.03	215.19	37.53	99.32	0.11	0.24	0.29	238.16
UA2012-059-986-35 AVERAGE	65.04	83.28	15.74	58.05	2.01	0.09	3567.25	17.42	114.78	0.04	0.30	0.33	313.95
UA2012-059-986-36 AVERAGE	103.14	347.34	37.68	76.25	2.75	0.29	14468.12	45.26	320.81	0.00	0.36	0.79	0.00

UA2012-059-986-39 AVERAGE	407.51	61.18	528.12	576.53	3.07	0.04	779.73	106.71	230.14	0.17	0.18	5.90	0.00
UA2012-059-986-41 AVERAGE	69.61	55.36	5.49	4.91	0.17	0.00	188.01	27.32	58.94	0.09	0.15	0.13	180.89
UA2012-059-986-43 AVERAGE	67.57	59.94	14.09	85.45	0.81	0.00	221.12	26.93	61.10	0.10	0.38	0.48	198.49
UA2012-059-986-45 AVERAGE	187.84	54.36	198.10	121.56	2.30	0.02	838.76	76.39	175.84	0.22	0.26	5.28	0.00
UA2012-059-986-49 AVERAGE	115.46	163.55	13.65	74.95	2.25	0.08	1968.91	37.11	132.38	0.08	0.20	0.30	0.00
UA2012-059-986-50 AVERAGE	116.00	247.67	32.84	65.91	1.67	0.03	7179.49	35.26	127.92	0.09	0.18	0.47	152.37
UA2012-059-986-51 AVERAGE	264.07	101.33	169.34	31.70	1.09	0.02	435.75	58.58	100.81	0.14	0.52	4.85	0.00
UA2012-059-986-52 AVERAGE	271.26	95.33	185.35	37.67	1.93	0.04	333.70	73.71	111.65	0.23	0.42	4.70	0.00
UA2012-059-986-57 AVERAGE	153.73	351.44	24.57	40.23	1.75	0.04	230.77	55.79	65.51	0.12	0.96	1.13	0.00
UA2012-059-986-58 AVERAGE	144.89	386.93	34.31	40.99	1.42	0.04	244.17	62.79	77.22	0.13	1.37	0.99	0.00
UA2012-059-967-2 AVERAGE	92.79	199.21	24.38	56.91	1.79	0.19	12443.07	25.20	229.25	0.00	0.19	0.54	0.00
UA2012-059-967-3 AVERAGE	49.01	126.84	14.37	28.37	0.87	0.05	9697.91	16.82	135.24	0.05	0.18	0.44	0.00
UA2012-059-967-4 AVERAGE	83.79	155.04	18.66	47.75	1.35	0.09	8615.47	27.21	192.91	0.00	0.16	0.35	195.09
UA2012-059-967-5 AVERAGE	78.51	194.78	21.61	49.24	1.22	0.08	15734.25	18.81	254.43	0.03	0.24	0.57	0.00
UA2012-059-967-8 AVERAGE	102.37	236.56	21.49	34.43	1.20	0.06	13224.09	22.75	247.06	0.11	0.20	0.56	0.00
UA2012-059-967-7 AVERAGE	142.71	363.35	28.79	53.92	1.33	0.16	18948.22	33.46	251.53	0.07	0.25	0.65	0.00
UA2012-059-967-11 AVERAGE	98.28	53.36	19.93	0.00	0.26	0.03	948.13	50.87	144.69	0.08	0.21	0.29	117.35
UA2012-059-967-12 AVERAGE	90.07	214.07	18.39	49.03	2.06	0.08	14115.96	27.30	233.08	0.02	0.18	0.48	0.00
UA2012-059-967-21 AVERAGE	281.37	630.83	42.06	61.06	1.82	0.18	27923.86	47.38	439.24	0.29	0.31	1.16	0.00
UA2012-059-967-23 AVERAGE	120.93	151.31	21.27	63.83	2.80	0.10	4906.81	40.44	166.92	0.07	0.24	0.34	0.00
UA2012-059-967-25 AVERAGE	67.87	46.42	20.31	20.73	1.03	0.00	2317.55	27.99	106.68	0.05	0.17	0.38	0.00
UA2012-059-967-31 AVERAGE	125.81	253.68	31.34	34.49	1.11	0.07	14030.80	25.45	249.20	0.07	0.22	0.71	0.00
UA2012-059-967-34 AVERAGE	112.18	213.62	18.86	47.63	2.38	0.09	8893.71	27.86	207.75	0.07	0.20	0.39	0.00
UA2012-059-967-37 AVERAGE	139.11	165.37	72.22	41.69	1.80	0.04	1199.98	36.84	97.74	0.08	0.37	3.72	0.00

UA2012-059-988-4 AVERAGE	95.68	60.32	12.53	4.09	0.06	0.00	1394.91	27.17	104.09	0.11	0.26	0.19	0.00
UA2012-059-973-1 AVERAGE	56.23	142.24	12.85	65.12	1.39	0.06	8793.93	7.83	139.85	0.01	0.16	0.33	0.00
UA2012-059-973-2 AVERAGE	92.95	212.13	24.78	60.14	1.94	0.14	15499.19	34.81	238.54	0.00	0.13	0.42	0.00
UA2012-059-973-3 AVERAGE	89.36	131.26	32.01	35.15	1.16	0.06	21148.42	31.07	246.46	0.00	0.17	1.08	0.00
UA2012-059-973-4 AVERAGE	237.68	104.45	160.60	34.46	1.16	0.02	350.34	60.44	97.10	0.14	0.53	5.07	0.00
UA2012-059-1157-1 AVERAGE	73.74	66.98	43.87	35.01	1.13	0.05	2311.18	33.69	137.42	0.06	0.31	0.71	0.00
UA2012-059-1157-2 AVERAGE	108.82	185.62	34.91	20.63	0.14	0.00	712.63	43.13	133.33	0.08	0.40	0.27	0.00
UA2012-059-1147-1 AVERAGE	185.59	298.57	54.41	20.99	0.28	0.02	514.87	59.81	33.74	0.12	0.82	3.71	0.00
UA2012-059-1147-2 AVERAGE	56.09	48.27	33.33	22.75	0.89	0.01	2568.12	46.22	180.52	0.02	0.33	0.85	0.00
UA2012-059-1154 AVERAGE	79.47	95.58	20.66	30.63	0.92	0.01	553.91	15.58	85.36	0.10	0.20	0.46	0.00
UA2012-059-1148-9 AVERAGE	69.53	106.22	13.36	38.68	1.41	0.07	5821.08	15.99	130.75	0.02	0.12	0.29	0.00
UA2012-059-1148-10 AVERAGE	99.04	111.54	17.14	23.60	0.27	0.05	1709.61	56.88	161.31	0.07	0.18	0.23	0.00
UA2012-059-1148-11 AVERAGE	80.29	119.88	24.06	58.73	2.51	0.11	9022.24	30.05	185.12	0.00	0.16	0.45	0.00
UA2012-059-1148-12 AVERAGE	334.18	91.72	177.18	90.61	3.63	0.05	4034.45	19.84	100.67	0.47	0.56	4.02	0.00
UA2012-059-1148-14 AVERAGE	122.79	240.45	29.75	42.37	0.80	0.03	12682.43	22.88	215.97	0.08	0.19	0.73	199.44
UA2012-059-1148-15 AVERAGE	121.58	260.62	26.01	53.01	1.99	0.07	11631.49	36.40	215.06	0.18	0.19	0.64	0.00
UA2012-059-1148-17AVERAGE	373.93	566.03	64.89	47.77	1.26	0.04	473.61	73.55	91.83	0.17	1.02	3.28	0.00
UA2012-059-1148-18 AVERAGE	262.77	53.69	132.46	26.86	1.53	0.02	456.25	43.54	89.43	0.07	0.29	5.89	0.00
UA2012-059-1151-1 AVERAGE	131.98	149.81	17.84	13.33	0.96	0.02	5796.60	37.79	194.76	0.06	0.23	0.38	0.00
UA2012-059-1151-3 AVERAGE	116.92	249.07	12.07	38.42	3.04	0.04	580.81	21.93	82.48	0.16	0.80	0.41	0.00
UA2012-059-1151-4 AVERAGE	65.32	93.82	11.84	21.17	0.92	0.02	4575.77	33.24	139.93	0.03	0.14	0.17	0.00
UA2012-059-1151-5 AVERAGE	56.02	66.28	12.18	20.12	0.49	0.06	1106.34	38.35	63.62	0.02	0.14	0.14	0.00
UA2012-059-1151-6 AVERAGE	99.46	199.02	21.70	55.26	2.40	0.13	7934.60	40.54	196.28	0.05	0.24	0.48	0.00
UA2012-059-1151-10 AVERAGE	84.90	192.66	24.73	37.66	1.28	0.13	11046.38	31.79	218.40	0.02	0.17	0.53	0.00

UA2012-059-1156-1 AVERAGE	124.59	53.51	43.82	42.33	2.69	0.03	2903.01	41.40	131.78	0.13	0.21	0.84	0.00
UA2012-059-1156-2 AVERAGE	55.66	82.04	19.55	43.58	1.69	0.06	5342.75	34.85	181.35	0.01	0.19	0.44	0.00
UA2012-059-1156-3 AVERAGE	101.18	95.82	57.22	70.41	1.39	0.03	4166.54	57.96	243.58	0.06	0.22	1.20	145.22
UA2012-059-1156-4 AVERAGE	186.29	745.48	62.41	138.52	3.59	0.15	7753.59	68.78	216.02	0.21	0.38	1.09	0.00
UA2012-059-1156-7 AVERAGE	280.05	395.31	203.66	234.76	2.74	0.03	726.80	67.84	296.39	0.72	1.45	2.46	243.41
UA2012-059-1276 AVERAGE	116.72	341.88	26.77	184.20	2.04	0.26	15486.82	24.85	264.91	0.06	0.22	1.00	243.27
UA2012-059-1277 AVERAGE	93.20	103.06	16.57	13.50	0.45	0.02	4288.86	12.80	118.24	0.10	0.31	0.62	279.28
UA80-181-47b-1 AVERAGE	76.88	41.03	23.66	29.24	1.42	0.06	1843.53	16.12	86.16	0.10	0.10	0.41	0.00
UA80-181-47b-2 AVERAGE	93.09	33.79	27.80	24.03	1.50	0.06	2239.31	19.06	108.88	0.13	0.11	0.42	0.00
UA80-181-47b-3 AVERAGE	76.64	39.14	23.64	30.83	1.54	0.06	1741.10	13.62	73.15	0.11	0.10	0.33	0.00
UA80-181-47b-5 AVERAGE	77.36	65.41	12.19	34.16	1.59	0.08	1700.05	9.83	80.63	0.09	0.10	0.20	0.00
UA80-181-47b-6 AVERAGE	98.48	27.38	25.18	34.53	1.37	0.05	1212.70	26.68	85.97	0.14	0.12	0.37	0.00
UA80-181-47b-7 AVERAGE	85.16	31.92	15.53	4.38	0.06	0.00	952.41	22.81	102.19	0.13	0.10	0.22	120.52
UA80-181-47b-8 AVERAGE	73.55	42.15	24.24	28.33	1.49	0.06	2836.67	11.92	95.30	0.13	0.16	0.39	0.00
UA80-181-47b-9 AVERAGE	68.35	58.75	12.45	34.64	1.77	0.08	1424.12	11.41	74.72	0.09	0.09	0.21	0.00
UA80-181-47b-10 AVERAGE	91.99	38.67	16.58	44.08	2.41	0.08	941.54	25.68	83.76	0.16	0.13	0.33	0.00
UA80-181-47b-11 AVERAGE	83.07	44.36	25.98	25.93	1.48	0.06	2033.05	15.93	96.18	0.09	0.10	0.37	0.00
UA80-181-47b-12 AVERAGE	79.28	59.00	23.29	44.59	2.46	0.09	1709.28	31.33	98.24	0.09	0.11	0.30	0.00
UA80-181-47b-13 AVERAGE	101.37	45.29	27.85	42.76	2.26	0.09	1691.37	25.14	88.33	0.15	0.12	0.40	0.00
UA80-181-47b-15 AVERAGE	81.69	36.85	43.26	13.19	0.94	0.03	2882.45	21.81	119.09	0.14	0.12	0.68	138.49
UA80-181-47b-16 AVERAGE	136.95	48.41	12.58	42.66	2.87	0.10	696.28	39.40	108.13	0.19	0.09	0.18	318.87
UA80-181-47b-17 AVERAGE	92.07	44.71	24.51	0.00	0.11	0.02	744.82	42.84	117.32	0.13	0.13	0.34	0.00
UA80-181-47b-20 AVERAGE	68.59	44.55	20.02	31.39	1.56	0.07	2159.85	9.24	78.64	0.08	0.10	0.30	0.00
UA80-181-47b-21 AVERAGE	87.35	31.43	10.66	18.07	0.29	0.02	610.33	29.50	0.00	0.11	0.09	0.18	0.00

UA80-181-47b-24 AVERAGE	65.27	25.34	33.56	14.36	0.12	0.02	1420.89	33.59	116.51	0.16	0.13	0.48	0.00
UA80-181-47b-27 AVERAGE	85.86	32.21	41.69	18.04	1.25	0.05	2915.96	17.98	120.44	0.15	0.12	0.64	0.00
UA80-181-47b-30 AVERAGE	98.63	44.13	19.79	15.03	0.06	0.01	571.71	47.87	127.02	0.16	0.16	0.21	0.00
UA80-181-47b-32 AVERAGE	85.98	56.95	21.41	42.50	2.51	0.16	922.89	35.69	106.43	0.33	0.30	0.62	0.00
UA80-181-47b-34 AVERAGE	78.49	45.83	22.51	26.33	1.19	0.04	1423.71	28.29	112.03	0.15	0.10	0.34	0.00
UA80-181-47b-35 AVERAGE	114.70	33.82	43.33	0.00	0.18	0.04	1639.82	40.29	137.27	0.12	0.11	0.51	0.00
UA80-181-47b-36 AVERAGE	83.02	29.64	26.92	11.32	0.21	0.02	1571.59	21.41	85.56	0.11	0.11	0.40	0.00
UA80-181-47b-37 AVERAGE	89.85	44.17	32.10	39.19	2.06	0.12	2698.95	21.21	107.46	0.13	0.11	0.48	0.00
UA80-181-47b-40 AVERAGE	84.39	29.20	15.60	27.54	0.40	0.02	1109.76	15.76	76.31	0.11	0.10	0.28	183.63
UA80-181-47b-42 AVERAGE	136.40	45.08	48.55	11.37	0.14	0.02	1538.42	54.19	185.22	0.20	0.21	0.74	0.00
UA80-181-47b-45 AVERAGE	97.65	42.07	9.43	43.20	2.21	0.09	805.20	18.96	81.52	0.18	0.11	0.23	0.00
UA80-181-47b-46 AVERAGE	121.61	67.52	21.20	50.20	2.98	0.10	1315.32	36.02	94.24	0.18	0.20	0.38	0.00
UA80-181-47b-48 AVERAGE	114.44	54.08	22.12	49.82	2.75	0.10	1622.68	34.93	105.26	0.25	0.11	0.33	0.00
UA80-181-47b-49 AVERAGE	125.37	33.89	36.02	13.50	0.11	0.03	1203.25	44.53	131.29	0.12	0.09	0.36	190.58
UA80-181-47b-52 AVERAGE	78.26	50.76	19.76	13.35	1.46	0.08	840.12	28.03	94.07	0.13	0.19	0.38	0.00
UA80-181-47b-56 AVERAGE	77.02	31.72	27.18	22.30	0.30	0.02	1374.21	27.66	105.23	0.14	0.15	0.45	0.00
UA80-181-47b-57 AVERAGE	88.94	48.65	17.92	39.63	2.22	0.10	1986.21	13.93	67.53	0.12	0.11	0.29	0.00
UA80-181-47b-58 AVERAGE	125.70	52.95	34.56	32.86	1.73	0.11	1617.04	45.68	128.79	0.11	0.12	0.45	0.00
UA80-181-60-1 AVERAGE	191.18	155.03	38.67	67.61	2.77	0.04	2487.73	29.21	111.18	0.25	0.54	1.54	0.00
UA80-181-60-6 AVERAGE	87.98	44.58	16.66	31.05	1.43	0.05	1154.94	19.49	81.85	0.09	0.10	0.22	0.00
UA80-181-60-9 AVERAGE	174.20	106.49	38.84	81.70	2.90	0.25	1175.00	68.46	158.53	0.17	0.19	0.44	0.00
UA80-181-60-2 AVERAGE	72.11	41.04	27.10	34.46	1.88	0.06	3073.69	10.15	89.07	0.18	0.34	0.46	0.00
UA80-181-60-4 AVERAGE	112.68	44.25	17.61	38.62	1.89	0.09	1117.04	29.02	93.28	0.13	0.12	0.25	0.00
UA80-181-60-5 AVERAGE	59.77	45.50	16.49	28.25	1.50	0.06	1295.46	15.58	73.53	0.07	0.11	0.24	0.00

UA80-181-60-7 AVERAGE	117.42	54.14	42.52	16.26	0.32	0.02	2092.41	36.16	124.83	0.14	0.26	0.66	0.00
UA80-181-60-12 AVERAGE	108.82	41.86	33.96	40.73	1.83	0.08	1472.73	41.42	111.31	0.09	0.11	0.40	0.00
UA80-181-60-20 AVERAGE	92.39	49.34	11.66	30.07	1.51	0.10	950.51	22.12	83.71	0.11	0.11	0.27	0.00
UA80-181-60-24 AVERAGE	140.15	488.58	21.49	53.04	3.41	0.07	2027.87	24.39	100.45	0.21	1.15	0.75	0.00
UA80-181-60-27 AVERAGE	128.35	594.37	48.60	54.11	3.35	0.08	2835.91	27.32	133.77	0.23	1.50	1.49	0.00
UA80-181-60-31 AVERAGE	137.33	236.59	44.81	63.11	3.35	0.09	2599.58	35.59	122.81	0.21	0.62	1.40	0.00
UA80-181-60-32 AVERAGE	125.52	383.19	24.17	48.80	3.29	0.06	2282.09	16.27	110.39	0.18	0.81	0.83	0.00
UA80-181-60-34 AVERAGE	255.88	350.13	31.87	76.24	4.54	0.11	1519.77	43.35	151.56	0.17	0.67	0.96	0.00
UA80-181-60-35 AVERAGE	158.25	174.26	27.90	18.25	0.90	0.01	1323.08	29.74	107.85	0.17	0.51	1.07	0.00
UA80-181-60-36 AVERAGE	151.15	162.16	22.99	34.43	2.33	0.02	1413.15	17.90	93.75	0.14	0.47	0.78	0.00
UA80-181-60-37 AVERAGE	156.76	268.22	31.76	41.86	2.66	0.04	3859.79	22.15	117.12	0.24	0.66	1.08	0.00
UA80-181-60-38 AVERAGE	155.86	242.11	32.71	41.27	3.02	0.04	3448.72	24.40	85.32	0.23	0.67	0.96	0.00
UA80-181-60-39 AVERAGE	113.58	265.43	35.45	47.83	2.92	0.06	2401.33	17.37	103.95	0.16	0.54	1.07	0.00
UA80-181-60-40 AVERAGE	142.32	176.33	28.14	59.53	3.57	0.05	1499.81	30.53	117.88	0.23	0.58	0.83	0.00
UA80-181-60-48 AVERAGE	143.67	370.96	37.51	44.65	3.35	0.08	2818.63	27.18	127.83	0.16	0.79	1.44	0.00
UA80-181-60-54 AVERAGE	215.18	486.77	38.44	77.57	4.85	0.12	1249.04	50.57	156.81	0.17	0.85	1.08	0.00
UA80-181-60-59 AVERAGE	167.97	310.80	30.83	63.71	3.80	0.08	1786.53	29.95	114.08	0.17	0.61	0.93	0.00
UA80-181-60-60 AVERAGE	154.72	177.51	27.85	36.93	1.73	0.02	1656.40	23.87	108.09	0.22	0.52	0.96	0.00
UA80-181-60-62 AVERAGE	63.63	25.03	26.71	20.23	0.36	0.02	1876.13	16.48	89.37	0.11	0.17	0.45	0.00
UA80-181-60-61 AVERAGE	136.66	390.11	26.12	57.39	2.96	0.05	2563.63	21.54	124.88	0.22	0.83	0.84	0.00
UA80-181-60-64 AVERAGE	77.28	44.81	39.03	56.25	3.05	0.10	3369.31	13.09	96.80	0.19	0.78	0.59	0.00
UA80-181-60-65 AVERAGE	84.18	37.37	53.89	20.24	0.21	0.07	1641.65	57.27	160.36	0.15	0.25	0.86	180.91
UA80-181-60-71 AVERAGE	155.98	322.54	32.36	52.98	3.47	0.06	2572.93	31.51	126.61	0.18	0.75	1.01	0.00
UA80-181-60-72 AVERAGE	144.16	341.15	30.37	55.44	3.01	0.06	2810.46	19.21	109.91	0.19	0.73	1.03	0.00

UA80-181-60-76 AVERAGE	82.59	47.59	26.58	36.78	1.78	0.10	1641.80	921.77	67.50	0.09	0.14	0.28	0.00
UA80-181-60-77 AVERAGE	199.00	464.77	39.57	82.04	4.14	0.10	224.97	2479.54	0.70	0.00	0.85	0.00	0.00
UA80-181-60-78 AVERAGE	143.70	309.85	28.74	57.66	3.87	0.07	160.62	3010.38	0.00	0.00	0.82	0.00	0.00
UA80-181-60-84 AVERAGE	318.82	711.86	40.66	79.33	3.91	0.10	168.38	1681.07	0.00	0.00	1.53	0.00	0.00
UA80-181-60-90 AVERAGE	72.56	36.32	23.89	39.37	2.00	0.09	103.88	2346.09	0.00	0.00	0.12	0.00	0.00
UA80-181-60-91 AVERAGE	342.77	471.64	60.75	61.78	3.84	0.09	246.91	2449.21	0.00	0.00	1.28	0.00	0.00
UA80-181-60-99 AVERAGE	130.06	49.55	39.93	21.40	1.26	0.02	204.77	1745.21	4.48	0.00	0.88	0.00	0.00
UA80-181-60-101 AVERAGE	80.07	49.66	19.34	38.49	2.26	0.10	106.42	2143.94	0.00	0.00	0.18	0.00	0.00
UA80-181-60-110 AVERAGE	157.51	256.70	38.02	58.83	4.56	0.11	177.42	1467.50	0.00	0.00	0.83	0.00	0.00
UA80-181-60-112 AVERAGE	157.69	304.14	23.84	43.84	2.54	0.05	119.40	1711.21	0.00	0.00	0.76	0.00	0.00
UA80-181-60-113 AVERAGE	234.25	434.89	75.61	97.08	4.29	0.19	176.82	3511.95	0.00	0.00	1.38	0.00	0.00
UA80-181-60-117 AVERAGE	90.47	40.97	27.52	34.09	1.78	0.06	128.43	2175.09	0.00	0.00	0.18	0.00	0.00
UA80-181-60-126 AVERAGE	101.21	30.46	30.17	17.76	0.15	0.02	138.18	1352.24	0.00	0.00	0.14	0.00	0.00
UA80-181-60-130 AVERAGE	159.32	216.82	29.58	38.10	3.54	0.03	139.56	2284.42	0.00	0.00	0.54	0.00	0.00
UA80-181-60-142 AVERAGE	96.01	52.86	22.67	35.72	2.16	0.12	73.31	931.08	0.00	0.00	0.27	0.00	0.00
UA80-181-60-143 AVERAGE	61.53	23.43	17.16	4.20	0.14	0.01	137.55	841.50	3.04	0.00	0.17	0.00	0.00
UA80-181-60-155 AVERAGE	145.88	167.19	24.32	50.95	2.91	0.04	142.48	2397.11	0.00	0.00	0.39	0.00	0.00

UA80-181-60-156 AVERAGE	61.97	53.38	25.66	36.94	1.71	0.07	129.82	4387.63	0.00	0.00	0.22	0.00	0.00
UA80-181-60-157 AVERAGE	73.15	34.65	23.82	34.07	2.07	0.07	95.52	1915.04	0.00	0.00	0.12	0.00	0.00
UA80-181-60-158 AVERAGE	154.75	209.88	53.78	34.46	1.94	0.04	182.52	2978.87	0.00	0.00	0.59	0.00	0.00
UA80-181-60-159 AVERAGE	137.99	356.32	24.52	58.78	3.47	0.07	151.37	2827.66	0.00	0.00	0.68	0.00	0.00
UA80-181-60-160 AVERAGE	161.73	240.61	30.50	60.41	2.48	0.05	167.44	2345.26	0.00	0.00	0.70	0.00	0.00
UA80-181-60-164 AVERAGE	143.48	191.64	22.63	53.53	2.36	0.04	119.80	2265.16	0.00	0.00	0.55	0.00	0.00
UA80-181-60-166 AVERAGE	124.10	282.60	32.70	36.36	3.14	0.04	175.11	1907.66	0.00	0.00	0.80	0.00	0.00
UA80-181-60-167 AVERAGE	163.87	306.29	30.95	54.98	3.52	0.06	165.99	1852.47	0.00	0.00	0.88	0.00	0.00
UA80-181-60-169 AVERAGE	156.98	206.05	38.69	47.45	2.61	0.04	162.21	1694.98	0.00	0.00	0.75	0.00	0.00
UA80-181-60-172 AVERAGE	70.54	44.51	23.11	39.48	2.02	0.09	98.07	2698.59	0.00	0.00	0.09	0.00	0.00
UA80-181-60-173 AVERAGE	130.46	359.16	27.20	50.80	3.58	0.06	144.50	1712.07	0.00	0.00	0.81	0.00	0.00
UA80-181-60-175 AVERAGE	112.57	358.05	49.92	43.22	2.91	0.09	189.13	3461.04	0.00	0.00	1.50	0.00	0.00
UA80-181-60-176 AVERAGE	76.09	39.56	24.63	35.65	1.83	0.08	111.82	2784.32	0.00	0.00	0.12	0.00	0.00
UA80-181-60-177 AVERAGE	119.58	329.18	19.83	47.64	2.64	0.05	116.68	2002.69	0.00	0.00	0.71	0.00	0.00
UA80-181-60-178 AVERAGE	104.06	41.30	44.13	23.91	1.51	0.06	149.52	3431.62	0.00	0.00	0.14	0.00	0.00
UA80-181-60-179 AVERAGE	151.04	200.38	47.08	42.90	2.51	0.06	164.92	2828.20	0.00	0.00	0.55	0.00	0.00

UA80-181-60-181 AVERAGE	155.72	280.74	34.26	57.85	3.91	0.08	161.77	1659.47	0.00	0.00	0.73	0.00	0.00
UA80-181-60-184 AVERAGE	177.15	290.93	38.30	37.04	2.90	0.04	168.04	1743.04	0.00	0.00	1.07	0.00	0.00
UA80-181-60-185 AVERAGE	159.76	302.42	36.03	44.08	3.11	0.05	182.96	2034.40	2.32	0.00	1.00	0.00	0.00
UA80-181-60-186 AVERAGE	233.51	335.11	46.78	80.38	4.22	0.10	146.31	2854.06	0.00	0.00	0.55	0.00	0.00
UA80-181-60-189 AVERAGE	75.73	46.27	12.69	19.65	0.83	0.02	135.87	849.73	0.00	0.00	0.13	0.00	0.00
UA80-181-60-190 AVERAGE	109.41	32.90	41.21	0.00	0.15	0.02	173.25	1930.52	0.00	0.00	0.15	0.00	0.00
UA80-181-60-191 AVERAGE	102.34	31.96	23.62	0.00	0.11	0.02	55.58	813.37	0.00	0.00	0.13	0.00	0.00
UA80-181-60-192 AVERAGE	76.18	34.09	20.36	31.20	2.05	0.06	88.99	1581.63	0.00	0.00	0.16	0.00	0.00
UA80-181-60-194 AVERAGE	374.09	374.13	54.27	48.21	3.54	0.09	235.18	1047.68	0.00	0.00	0.77	0.00	0.00
UA80-181-60-196 AVERAGE	63.92	37.34	19.74	51.23	2.24	0.10	48.69	2367.82	0.00	0.00	0.10	0.00	0.00
UA80-181-60-197 AVERAGE	99.30	43.83	30.37	50.05	2.29	0.10	147.78	2645.66	0.00	0.00	0.14	0.00	0.00
UA80-181-60-198 AVERAGE	106.37	31.59	19.18	26.09	1.49	0.08	131.60	1052.34	2.87	0.00	0.18	0.00	0.00
UA80-181-60-199 AVERAGE	137.09	404.34	28.78	42.98	2.99	0.07	138.80	3083.20	0.00	0.00	0.81	0.00	0.00
UA80-181-60-203 AVERAGE	145.28	283.79	28.06	49.37	3.66	0.07	156.42	1715.29	0.00	0.00	0.74	0.00	0.00
UA80-181-60-202 AVERAGE	187.27	292.39	33.27	54.45	3.48	0.05	176.19	3310.64	0.00	0.00	0.73	0.00	0.00
UA80-181-60-201 AVERAGE	172.26	204.04	30.22	65.57	4.47	0.06	174.09	2281.91	0.00	0.00	0.58	0.00	0.00
UA80-181-60-200 AVERAGE	146.93	338.75	36.22	55.91	3.59	0.06	162.64	2817.68	0.00	0.00	0.77	0.00	0.00

UA80-181-60-205 AVERAGE	162.53	399.63	29.29	61.10	4.35	0.11	115.31	1619.73	0.00	0.00	0.80	0.00	0.00
UA80-181-60-207 AVERAGE	114.42	437.47	24.11	48.05	3.28	0.06	159.98	2633.56	0.00	0.00	0.91	0.00	0.00
UA80-181-60-208 AVERAGE	85.82	73.48	15.37	41.37	1.99	0.10	123.60	2865.67	0.00	0.00	0.10	0.00	0.00
UA80-181-60-209 AVERAGE	82.50	56.04	18.20	19.89	1.25	0.07	141.39	865.98	0.99	0.00	0.13	0.00	0.00
UA80-181-60-211 AVERAGE	138.19	76.02	18.60	37.00	2.22	0.11	140.66	835.74	4.18	0.00	0.20	0.00	0.00
UA80-181-60-212 AVERAGE	129.12	42.08	23.18	25.28	1.48	0.10	146.47	1129.86	3.54	0.00	0.11	0.00	0.00
UA80-181-60-213 AVERAGE	103.38	48.66	23.98	43.42	2.19	0.09	117.53	1764.57	0.00	0.00	0.10	0.00	0.00
UA80-181-60-223 AVERAGE	137.00	235.28	28.86	62.49	3.58	0.06	158.64	2854.03	0.00	0.00	0.64	0.00	0.00
UA80-181-60-217 AVERAGE	154.27	224.97	27.18	57.99	3.97	0.07	146.41	1870.47	0.00	0.00	0.65	0.00	0.00
UA80-181-60-218 AVERAGE	154.73	249.77	25.93	55.70	2.76	0.04	142.31	2774.51	0.00	0.00	0.64	0.00	0.00
UA80-181-60-221 AVERAGE	126.49	317.00	38.93	55.11	2.89	0.05	115.28	1832.92	0.00	0.00	0.82	0.00	0.00
UA80-181-60-222 AVERAGE	187.19	290.77	31.04	56.72	3.97	0.07	177.73	1669.80	0.00	0.00	0.78	0.00	0.00
UA80-181-60-224 AVERAGE	217.12	378.15	25.76	75.81	4.33	0.12	165.38	2054.75	0.39	0.00	0.88	0.00	0.00
UA80-181-60-225 AVERAGE	129.33	477.65	24.85	49.62	3.18	0.07	144.45	4397.45	0.00	0.00	0.94	0.00	0.00
UA80-181-60-226 AVERAGE	159.97	223.53	28.65	50.29	1.76	0.03	118.68	2286.73	0.00	0.00	0.61	0.00	0.00
UA80-181-60-230 AVERAGE	149.32	168.04	23.92	37.35	2.12	0.03	106.71	2053.30	0.00	0.00	0.45	0.00	0.00
UA80-181-60-231 AVERAGE	177.84	128.35	36.12	37.94	1.72	0.02	185.87	1848.87	0.00	0.00	0.40	0.00	0.00

UA80-181-60-232 AVERAGE	396.80	377.44	58.08	114.70	6.33	0.16	268.91	2199.33	6.14	0.00	0.85	0.00	0.00
UA80-181-60-235 AVERAGE	157.60	346.19	27.83	70.12	4.10	0.09	155.63	1185.68	3.85	0.00	1.04	0.00	0.00
UA80-181-60-246 AVERAGE	142.77	187.30	33.84	40.33	3.07	0.06	157.40	1830.98	0.00	0.00	0.52	0.00	0.00
UA80-181-60-247 AVERAGE	99.00	42.05	34.62	18.11	0.30	0.01	161.40	1721.47	0.00	0.00	0.17	0.00	0.00
UA80-181-60-248 AVERAGE	122.73	67.01	27.08	22.21	1.17	0.05	180.08	1098.61	0.00	0.00	0.19	0.00	0.00
UA80-181-60-251 AVERAGE	96.61	24.43	11.30	3.09	0.11	0.00	70.74	593.64	0.00	0.00	0.18	0.00	0.00
UA80-181-60-253 AVERAGE	124.21	37.33	19.59	17.61	0.14	0.02	150.50	670.93	2.80	0.00	0.28	0.00	0.00
UA80-181-60-256 AVERAGE	80.29	33.49	24.79	36.55	1.53	0.06	112.30	1617.12	3.01	0.00	0.14	0.00	0.00
UA80-181-60-257 AVERAGE	133.78	328.43	30.56	56.25	3.27	0.06	152.69	2573.25	0.00	0.00	0.78	0.00	0.00
UA80-181-60-258 AVERAGE	76.62	42.00	26.69	29.88	1.38	0.06	121.54	2394.12	0.00	0.00	0.10	0.00	0.00
UA80-181-60-260 AVERAGE	102.37	47.34	33.85	31.85	1.93	0.10	130.67	2432.57	0.00	0.00	0.15	0.00	0.00
UA80-181-60-268 AVERAGE	276.73	323.40	66.88	37.66	3.94	0.08	199.46	1850.98	0.00	0.00	0.89	0.00	0.00
UA80-181-60-272 AVERAGE	154.78	250.43	21.43	38.71	2.90	0.05	126.77	1721.85	0.00	0.00	0.65	0.00	0.00
UA80-181-60-276 AVERAGE	203.58	223.17	30.77	58.26	3.83	0.05	153.66	2413.55	0.00	0.00	0.81	0.00	0.00
UA80-181-60-278 AVERAGE	191.45	266.34	21.06	49.85	3.09	0.05	128.04	1876.59	0.00	0.00	0.76	0.00	0.00
UA80-181-60-280 AVERAGE	149.05	168.04	25.17	48.94	3.15	0.03	170.57	1673.43	0.00	0.00	0.53	0.00	0.00
UA80-181-60-281 AVERAGE	119.72	428.70	52.80	36.74	2.14	0.05	183.84	4355.31	0.00	0.00	1.58	0.00	0.00

UA80-181-60-285 AVERAGE	249.82	232.49	37.33	80.67	4.43	0.11	149.58	2781.68	0.00	0.00	0.65	0.00	0.00
UA80-181-60-288 AVERAGE	203.00	789.54	54.63	33.93	2.15	0.06	192.21	3093.39	0.00	0.00	2.73	0.00	0.00
UA80-181-60-291 AVERAGE	50.39	40.75	14.26	27.24	1.77	0.06	103.41	2424.58	0.00	0.00	0.12	0.00	0.00
UA80-181-60-292 AVERAGE	60.31	22.68	21.63	10.17	0.19	0.01	116.96	2233.94	0.00	0.00	0.09	0.00	0.00
UA80-181-60-293 AVERAGE	79.48	46.34	22.62	38.67	2.34	0.10	108.32	1676.51	0.47	0.00	0.09	0.00	0.00
UA80-181-60-297 AVERAGE	141.33	52.03	50.50	17.55	0.51	0.04	182.13	2223.42	0.00	0.00	0.15	0.00	0.00
UA80-181-60-307 AVERAGE	96.72	33.88	32.43	6.12	0.19	0.06	161.83	1217.40	0.00	0.00	0.21	0.00	0.00
UA80-181-60-309 AVERAGE	130.26	39.41	41.89	0.00	0.08	0.01	166.03	1785.02	0.00	0.00	0.13	0.00	0.00
UA80-181-60-310 AVERAGE	132.23	47.24	50.65	22.50	1.32	0.11	200.22	2471.03	0.00	0.00	0.17	0.00	0.00
UA80-181-60-311 AVERAGE	89.28	48.39	22.43	21.95	1.02	0.03	117.42	1481.40	0.00	0.00	0.13	0.00	0.00
UA80-181-60-312 AVERAGE	126.01	39.77	47.98	4.35	0.10	0.03	182.26	1760.66	2.74	0.00	0.17	0.00	0.00
UA80-181-60-313 AVERAGE	102.12	28.49	32.40	9.83	0.19	0.01	138.72	2001.92	0.00	0.00	0.09	0.00	0.00
UA80-181-60-315 AVERAGE	86.78	27.73	40.47	0.00	0.08	0.01	172.00	1799.75	3.83	0.00	0.14	0.00	0.00
UA80-181-60-318 AVERAGE	167.19	790.47	68.41	42.99	2.19	0.06	243.68	4863.57	0.00	0.00	2.69	0.00	0.00
UA2012-83 P916-919-61 AVERAGE	135.14	180.02	47.05	37.25	2.55	0.04	154.73	2954.10	0.00	0.00	0.57	0.00	0.00
UA2012-83 P916-919-62 AVERAGE	153.68	159.71	49.49	36.12	2.00	0.04	150.98	3451.95	0.00	0.00	0.56	0.00	0.00

UA2012-83 P916-919-63 AVERAGE	167.93	277.73	34.33	50.54	3.18	0.05	146.09	2081.92	0.00	0.00	0.91	0.00	0.00
UA2012-83 P916-919-64 AVERAGE	122.49	324.18	36.52	37.94	1.93	0.06	148.18	4398.07	0.00	0.00	0.62	0.00	0.00
UA2012-83 P916-919-65 AVERAGE	163.01	271.94	31.23	58.00	3.78	0.04	180.75	1241.16	0.00	0.00	0.87	0.00	0.00
UA2012-83 P916-919-66 AVERAGE	157.09	159.47	28.99	17.23	1.68	0.02	128.09	1180.60	3.57	0.00	0.81	0.00	0.00
UA2012-83 P916-919-94 AVERAGE	165.81	296.06	26.94	46.61	3.42	0.05	151.15	1969.91	0.00	0.00	0.80	0.00	0.00
UA2012-83 P916-919-74 AVERAGE	161.13	144.67	40.65	30.11	2.43	0.04	155.29	2630.98	0.00	0.00	0.64	0.00	0.00
UA2012-83 P916-919-77 AVERAGE	191.44	328.43	33.74	38.01	2.22	0.04	141.20	2921.48	0.00	0.00	0.91	0.00	0.00
UA2012-83 P916-919-78 AVERAGE	137.98	318.44	22.31	42.52	2.64	0.05	125.97	1642.99	0.00	0.00	0.81	0.00	0.00
UA2012-83 P916-919-80 AVERAGE	193.29	221.26	38.24	60.59	3.82	0.05	179.97	2580.25	0.00	0.00	0.89	0.00	0.00
UA2012-83 P916-919-83 AVERAGE	227.97	256.88	34.23	41.34	2.23	0.02	105.57	1676.83	0.00	0.00	0.89	0.00	0.00
UA2012-83 P916-919-82 AVERAGE	156.27	241.37	27.79	60.15	3.69	0.06	123.02	1972.44	0.00	0.00	0.73	0.00	0.00
UA2012-83 P916-919-85 AVERAGE	163.11	181.67	31.11	41.95	2.93	0.03	131.24	1764.60	0.00	0.00	0.70	0.00	0.00
UA2012-83 P916-919-87 AVERAGE	187.06	193.16	28.01	42.05	1.47	0.03	124.55	2086.42	0.00	0.00	0.67	0.00	0.00
UA2012-83 P916-919-88 AVERAGE	162.73	233.06	36.22	45.87	3.35	0.04	149.18	1750.82	0.00	0.00	0.75	0.00	0.00
UA2012-83 P916-919-90 AVERAGE	133.07	151.58	56.19	22.51	1.28	0.02	171.07	3937.77	0.00	0.00	0.49	0.00	0.00
UA2012-83 P899, -P903-3 AVERAGE	172.14	152.01	52.44	23.40	1.54	0.01	130.70	3373.77	0.00	0.00	0.67	0.00	0.00

UA2012-83 P899, -P903-5 AVERAGE	144.76	202.12	59.26	31.68	2.22	0.04	201.70	3691.23	0.00	0.00	0.60	0.00	0.00
UA2012-83 P899, -P903-7 AVERAGE	158.45	262.93	38.86	50.78	3.70	0.06	181.15	1479.17	0.00	0.00	0.88	0.00	0.00
UA2012-83 P899, -P903-8 AVERAGE	139.25	176.89	47.08	46.91	2.45	0.04	150.72	2876.93	0.00	0.00	0.49	0.00	0.00
UA2012-83 P899, -P903-9 AVERAGE	195.33	285.69	30.89	54.88	3.35	0.06	171.78	1204.61	0.00	0.00	0.91	0.00	0.00
UA2012-83 P899, -P903-12 AVERAGE	132.46	185.46	68.25	39.16	2.36	0.07	156.87	3823.98	0.00	0.00	0.53	0.00	0.00
UA2012-83 P899, -P903-15 AVERAGE	129.29	149.93	15.74	29.16	0.29	0.08	174.07	1788.11	8.04	0.00	0.21	0.00	0.00
UA2012-83 P910-913&915-44 AVERAGE	153.46	205.36	37.71	32.55	1.91	0.02	160.69	2791.05	0.00	0.00	0.72	0.00	0.00
UA2012-83 P910-913&915-46 AVERAGE	160.72	173.15	37.68	31.29	2.63	0.04	156.60	2811.16	0.00	0.00	0.63	0.00	0.00
UA2012-83 P910-913&915-49 AVERAGE	109.81	224.80	41.17	45.22	2.34	0.04	138.93	2639.33	0.00	0.00	0.62	0.00	0.00
UA2012-83 P910-913&915-51 AVERAGE	165.88	310.51	30.12	60.39	3.12	0.05	148.73	1631.14	0.00	0.00	0.84	0.00	0.00
UA2012-83 P910-913&915-53 AVERAGE	125.23	255.53	38.88	43.61	2.66	0.05	144.77	2585.28	0.00	0.00	0.65	0.00	0.00
UA2012-83 P910-913&915-54 AVERAGE	186.85	187.15	38.89	23.03	1.62	0.02	141.87	2791.01	0.00	0.00	0.72	0.00	0.00
UA2012-83 P910-913&915-56 AVERAGE	126.10	312.57	29.67	49.82	3.18	0.06	159.59	2969.98	0.00	0.00	0.75	0.00	0.00
UA2012-83 P910-913&915-57 AVERAGE	177.44	280.07	37.14	38.77	2.38	0.04	1519.38	843.46	70.52	0.18	0.97	0.80	0.00
UA2012-83 P910-913&915-58 AVERAGE	197.08	537.78	34.51	36.05	2.06	0.07	1083.23	43.19	92.22	0.27	2.45	1.10	0.00
UA2012-83 P910-913&915-59 AVERAGE	213.50	188.14	33.29	48.10	2.45	0.04	1803.78	31.51	113.76	0.31	0.75	0.91	0.00
UA2012-83 P910-913&915-60 AVERAGE	113.51	230.80	37.18	38.93	2.79	0.05	2164.88	18.41	100.96	0.23	0.67	1.15	0.00
UA2012-83 P910-913&915-62 AVERAGE	144.37	249.95	24.69	57.56	3.26	0.04	1334.71	22.53	102.20	0.27	0.56	0.88	0.00

UA2012-83 P910-913&915-3 AVERAGE	54.92	33.95	5.40	15.14	0.31	0.00	130.41	27.16	31.03	0.09	0.12	0.11	0.00
UA2012-83 P910-913&915-5 AVERAGE	340.97	293.17	42.45	58.40	3.36	0.06	801.22	67.10	148.49	0.32	0.89	0.89	0.00
UA2012-83 P910-913&915-13 AVERAGE	163.69	173.00	70.90	27.42	1.79	0.02	2899.06	28.96	111.34	0.30	0.77	1.57	0.00
UA2012-83 P910-913&915-19 AVERAGE	338.15	411.93	35.43	87.06	3.81	0.07	906.37	61.13	142.21	0.50	1.14	1.11	0.00
UA2012-83 P910-913&915-22 AVERAGE	148.99	194.34	59.15	36.76	2.07	0.04	2355.40	55.20	112.80	0.31	0.78	1.81	0.00
UA2012-83 P910-913&915-28 AVERAGE	168.05	274.69	14.22	16.33	1.64	0.02	255.86	40.83	118.16	0.30	1.77	0.36	0.00
UA2012-83 P910-913&915-29 AVERAGE	234.58	215.33	45.14	52.76	3.32	0.05	1502.91	44.06	128.00	0.35	0.89	1.45	0.00
UA2012-83 P910-913&915-30 AVERAGE	93.23	94.53	15.11	0.00	0.17	0.06	449.02	72.87	160.00	0.31	0.29	0.29	0.00
UA2012-83 P910-913&915-34 AVERAGE	150.75	90.83	83.96	71.32	2.72	0.07	2109.60	52.26	139.80	0.36	0.32	0.97	0.00
UA2012-83 P910-913&915-36 AVERAGE	197.80	173.97	80.11	34.77	1.70	0.02	2137.36	64.28	185.14	0.52	0.89	2.28	0.00
UA2012-83 P910-913&915-37 AVERAGE	129.03	221.01	53.50	59.45	4.04	0.12	2520.60	30.70	131.03	0.18	0.86	1.58	0.00
UA2012-83 P910-913&915-52 AVERAGE	108.88	68.33	9.06	0.00	0.09	0.00	0.00	53.78	124.02	0.14	0.22	0.50	0.00
UA2012-83 P904-907-1 AVERAGE	156.26	236.75	38.61	41.06	2.44	0.04	1985.57	22.32	108.18	0.27	0.89	1.17	0.00
UA2012-83 P899, 900, 902, 903-11 AVERAGE	142.42	169.20	72.60	33.95	2.54	0.05	3682.43	40.13	148.96	0.27	0.51	2.02	0.00
UA2012-83 P899, 900, 902, 903-12 AVERAGE	131.48	51.98	9.96	11.47	0.12	0.00	0.00	63.08	88.84	0.15	0.21	0.15	0.00
UA2012-83 P899, 900, 902, 903-13 AVERAGE	169.35	201.13	89.40	13.44	1.37	0.02	2809.24	59.57	163.43	0.34	0.80	2.73	0.00
UA2012-83 P899, 900, 902, 903-20 AVERAGE	172.69	154.76	25.28	41.21	2.79	0.04	1387.59	35.65	110.35	0.32	0.77	0.74	0.00
UA2012-83 P899, 900, 902, 903-27 AVERAGE	319.48	330.65	81.33	87.53	3.87	0.11	2019.42	74.87	188.09	0.42	0.98	2.43	0.00
UA2012-83 P899, 900, 902, 903-29 AVERAGE	266.95	377.78	78.21	83.14	4.16	0.11	2446.56	51.73	175.18	0.28	0.87	2.14	0.00
UA2012-83 P899, 900, 902, 903-30 AVERAGE	126.47	284.13	25.23	38.52	2.32	0.04	1627.75	15.82	107.74	0.23	0.68	0.72	0.00
UA2012-83 P899, 900, 902, 903-31 AVERAGE	196.84	309.23	47.29	38.73	3.41	0.05	1661.94	53.90	145.06	0.37	0.94	1.24	0.00
UA2012-83 P899, 900, 902, 903 AVERAGE	133.03	209.50	48.41	27.15	2.01	0.02	1647.55	35.83	112.34	0.29	0.76	1.30	0.00
UA2012-83 P899, 900, 902, 903-33 AVERAGE	205.13	348.85	46.38	53.07	4.16	0.08	1868.38	46.32	150.44	0.29	0.93	1.23	0.00
UA2012-83 P899, 900, 902, 903-34 AVERAGE	256.63	506.87	62.42	57.08	2.58	0.05	2988.81	49.05	167.46	0.36	1.16	1.85	0.00

UA2012-83 P899, 900, 902, 903-35 AVERAGE	144.03	127.84	66.42	41.83	2.66	0.03	2591.57	37.35	157.07	0.31	0.57	1.79	0.00
UA2012-83 P899, 900, 902, 903-38 AVERAGE	168.62	133.25	69.07	34.56	3.47	0.04	3058.96	38.74	142.45	0.33	0.67	1.98	0.00
UA2012-83 P899, 900, 902, 903-39 AVERAGE	152.17	155.43	52.35	34.51	2.06	0.02	2544.94	29.33	109.98	0.30	0.64	1.53	0.00
UA2012-83 P899, 900, 902, 903-41 AVERAGE	143.81	191.94	45.31	37.40	2.44	0.07	2073.86	44.04	139.16	0.26	0.66	1.32	0.00
UA2012-83 P899, 900, 902, 903-47 AVERAGE	141.84	328.75	44.13	43.78	2.23	0.05	2790.51	35.01	134.65	0.29	0.82	1.24	0.00
UA2012-83 P899, 900, 902, 903-49 AVERAGE	180.84	179.22	6.86	12.91	1.43	0.02	0.00	46.71	96.91	0.26	0.72	0.09	0.00
UA2012-83 P899, 900, 902, 903-56 AVERAGE	201.78	174.89	99.72	0.00	0.97	0.01	2539.10	64.21	163.88	0.35	1.11	1.78	0.00
UA2012-83 P899, 900, 902, 903-1 AVERAGE	168.42	172.91	46.74	38.99	2.73	0.02	2069.74	37.49	132.99	0.36	0.83	1.19	0.00
UA2012-83 P899, 900, 902, 903-2 AVERAGE	151.43	134.64	56.30	39.91	2.80	0.02	1274.83	42.33	116.47	0.37	0.80	1.14	0.00
UA2012-83 P899, 900, 902, 903-5 AVERAGE	160.20	362.65	43.81	56.26	4.21	0.10	2009.72	30.99	124.50	0.27	0.74	1.18	0.00
UA2012-83 P904 -907-8 AVERAGE	144.36	165.12	56.70	20.69	1.61	0.02	1915.83	32.88	115.94	0.28	0.67	1.54	0.00
UA2012-83 P904 -907-11 AVERAGE	166.73	120.94	60.37	31.83	1.59	0.02	2500.74	34.96	112.42	0.25	0.58	1.86	0.00
UA2012-83 P904 -907-12 AVERAGE	146.29	272.25	49.78	63.53	3.91	0.09	2426.85	33.40	123.58	0.26	0.78	1.59	0.00
UA2012-83 P904 -907-17 AVERAGE	182.31	292.21	31.21	64.03	3.97	0.06	743.42	42.31	119.54	0.37	1.20	0.54	0.00
UA2012-83 P904 -907-23 AVERAGE	195.66	182.59	47.29	39.54	2.52	0.04	2528.29	29.04	117.22	0.28	0.75	1.38	0.00
UA2012-83 P904 -907-32 AVERAGE	166.05	190.81	46.56	41.07	3.86	0.07	1579.42	47.80	143.53	0.34	0.71	1.26	0.00
UA2012-83 P916-919-91 AVERAGE	108.80	103.60	95.00	24.02	1.51	0.03	4047.95	22.96	119.18	0.17	0.37	2.17	0.00
UA2012-83 P916-919-92 AVERAGE	161.81	127.73	54.44	19.63	1.67	0.02	2463.21	39.56	140.61	0.24	0.41	1.58	0.00
UA2012-83 P916-919-93 AVERAGE	133.27	340.88	44.11	49.25	2.95	0.07	2745.58	21.60	125.87	0.20	0.81	1.18	0.00
UA2012-83 P916-919-95 AVERAGE	119.24	236.73	22.68	50.29	3.32	0.06	1408.01	17.95	89.91	0.22	0.64	0.62	0.00
UA2012-83 P916-919-97 AVERAGE	154.82	143.72	44.82	59.53	2.86	0.08	3101.55	17.44	104.82	0.20	0.50	1.40	0.00
UA2012-83 P916-919-101 AVERAGE	112.68	286.32	44.79	48.73	3.09	0.05	2752.99	23.92	123.26	0.22	0.71	1.33	0.00
UA2012-83 P916-919-102 AVERAGE	137.26	180.47	47.93	37.87	2.11	0.03	2520.67	27.51	128.55	0.27	0.67	1.51	0.00
UA2012-83 P916-919-104 AVERAGE	127.13	245.76	74.94	28.87	1.93	0.06	4725.15	16.47	121.86	0.20	0.55	2.07	0.00

UA2012-83 P916-919-107 AVERAGE	183.49	396.79	26.13	117.31	5.39	0.15	1190.45	32.49	120.47	0.21	0.81	0.76	0.00
UA2012-83 P916-919-108 AVERAGE	254.67	310.55	44.30	88.42	5.12	0.15	2019.15	41.90	134.67	0.29	0.73	1.15	0.00
UA2012-83 P916-919-110 AVERAGE	121.07	223.74	34.33	38.86	2.79	0.04	1374.51	30.57	115.74	0.22	0.69	0.92	0.00
UA2012-83 P916-919-114 AVERAGE	178.39	460.13	29.71	56.80	3.40	0.07	2359.74	22.52	110.87	0.29	1.30	0.90	0.00
UA2012-83 P916-919-118 AVERAGE	195.03	235.84	49.55	42.08	3.10	0.06	2033.55	36.84	121.12	0.27	0.58	1.29	339.17
UA2012-83 P916-919-121 AVERAGE	173.63	163.76	65.80	30.80	2.73	0.02	2552.63	25.73	111.56	0.39	0.64	1.25	0.00
UA2012-83 P916-919-125 AVERAGE	96.38	133.84	14.80	49.57	1.89	0.07	8081.47	12.27	133.30	0.09	0.13	0.38	0.00
UA2012-83 P916-919-126 AVERAGE	177.84	357.17	24.75	43.22	2.75	0.05	1192.44	39.99	119.01	0.31	0.95	0.65	0.00
UA2012-83 P916-919-129 AVERAGE	77.33	89.54	8.45	8.71	0.11	0.01	457.34	31.69	25.71	0.14	0.12	0.13	0.00
UA2012-83 P908-11 AVERAGE	171.11	238.29	43.63	50.65	2.90	0.05	3185.66	29.67	141.76	0.31	0.79	1.20	0.00
UA2012-83 P908-5 AVERAGE	134.44	212.95	39.71	40.85	2.70	0.04	1383.32	33.78	93.47	0.27	0.72	1.02	0.00
UA2012-83 P908-6 AVERAGE	130.60	175.67	41.97	33.80	2.04	0.03	1844.84	26.33	117.21	0.24	0.66	1.08	0.00
UA2012-83 P908-20 AVERAGE	366.39	246.76	57.61	47.05	3.08	0.04	2007.83	51.90	152.75	0.42	1.10	1.56	0.00
UA2012-83 P908-24 AVERAGE	143.83	198.63	67.52	35.94	2.83	0.04	2969.35	36.22	104.47	0.27	0.67	1.78	0.00
UA2012-83 P908-36 AVERAGE	120.86	262.19	50.85	51.20	3.39	0.06	2833.01	23.37	110.33	0.22	0.69	1.65	0.00
UA2012-83 P908-40 AVERAGE	134.54	161.24	101.99	23.57	1.57	0.03	3567.77	40.42	153.66	0.24	0.55	2.95	0.00
UA2012-83 P908-43 AVERAGE	167.46	284.93	42.03	45.01	3.08	0.03	1748.46	40.22	123.51	0.38	0.95	1.39	0.00
UA2012-83 P908-45 AVERAGE	153.91	250.29	49.28	45.52	3.38	0.04	2040.78	38.04	135.13	0.32	0.92	1.15	0.00
UA2012-83 P908-48 AVERAGE	307.03	373.61	89.46	59.78	3.50	0.08	2274.10	69.56	170.40	0.39	1.02	2.25	0.00
UA2012-83 P908-49 AVERAGE	159.00	247.07	54.48	31.15	1.57	0.04	1638.16	60.82	147.64	0.35	1.07	1.55	0.00
UA2012-83 P908-1 AVERAGE	142.92	249.58	53.27	38.05	1.73	0.04	3898.92	17.87	121.31	0.19	0.62	1.69	0.00
UA2012-83 P908-63 AVERAGE	201.69	160.09	1.44	20.25	1.23	0.01	0.00	33.78	85.70	0.23	0.57	0.10	176.63
UA2012-83 P908-64 AVERAGE	179.03	175.54	0.00	25.42	1.54	0.01	41.03	30.62	104.77	0.20	0.56	0.07	0.00
UA2012-83 P916-919-1 AVERAGE	168.10	162.48	61.82	53.85	3.82	0.07	2601.53	42.44	129.03	0.31	0.85	1.78	0.00

UA2012-83 P916-919-2 AVERAGE	184.70	174.11	68.13	47.96	2.80	0.05	2559.58	41.14	159.58	0.30	0.63	2.05	0.00
UA2012-83 P916-919-4 AVERAGE	147.67	290.57	21.71	44.47	2.86	0.04	1251.88	22.58	101.98	0.26	0.81	0.68	0.00
UA2012-83 P916-919-5 AVERAGE	60.20	99.69	13.36	33.80	1.04	0.03	4665.48	27.23	146.51	0.00	0.18	0.24	0.00
UA2012-83 P916-919-7 AVERAGE	131.66	123.26	26.87	33.32	1.75	0.02	631.95	30.34	112.83	0.20	0.50	0.47	0.00
UA2012-83 P916-919-11 AVERAGE	221.12	141.67	62.26	36.80	2.90	0.04	2300.12	51.74	134.97	0.43	0.78	1.69	0.00
UA2012-83 P916-919-22 AVERAGE	277.04	373.77	77.27	91.59	5.29	0.16	1896.13	66.66	178.52	0.36	0.94	1.89	0.00
UA2012-83 P916-919-36 AVERAGE	177.90	289.87	65.55	47.31	2.74	0.03	2392.15	47.03	144.88	0.40	1.23	1.69	0.00
UA2012-83 P916-919-41 AVERAGE	164.82	187.93	31.00	42.25	3.41	0.04	1467.70	32.90	116.74	0.33	0.69	0.96	0.00
UA2012-83 P916-919-46 AVERAGE	197.92	216.58	41.97	18.83	1.55	0.01	1694.02	39.51	128.04	0.44	0.99	1.29	0.00
UA2012-83 P916-919-54 AVERAGE	82.32	87.09	44.05	21.89	0.32	0.00	143.50	41.39	155.46	0.06	0.31	0.77	0.00
p910-913+915-64 AVERAGE	192.42	169.44	0.00	20.18	1.49	0.01	63.72	28.72	94.40	0.24	0.57	0.15	0.00
p910-913+915-65 AVERAGE	199.53	214.78	3.28	21.85	1.93	0.02	0.00	37.63	99.42	0.21	0.75	0.14	0.00
p910-913+915-66 AVERAGE	171.96	152.04	0.00	18.04	1.37	0.01	187.32	24.13	90.65	0.17	0.47	0.06	0.00
p910-913+915-70 AVERAGE	120.12	309.34	44.43	41.46	2.40	0.08	3550.07	27.13	135.80	0.20	0.72	1.56	0.00
p910-913+915-71 AVERAGE	133.54	138.24	37.88	28.93	1.31	0.01	1853.38	21.50	100.03	0.26	0.63	1.10	0.00
p910-913+915-72 AVERAGE	129.01	291.43	49.52	42.78	2.39	0.04	3850.93	16.00	131.60	0.20	0.71	1.53	0.00
p910-913+915-75 AVERAGE	148.68	219.13	42.35	50.11	2.60	0.04	2576.66	18.58	108.53	0.25	0.68	1.34	0.00
p910-913+915-79 AVERAGE	137.98	288.47	35.44	37.59	2.06	0.04	2952.87	18.64	103.14	0.22	0.61	1.09	0.00
p910-913+915-82 AVERAGE	154.49	244.75	30.19	52.62	2.97	0.04	1434.24	19.06	98.03	0.26	0.66	0.82	0.00
p910-913+915-92 AVERAGE	188.87	132.45	69.81	26.31	2.06	0.03	2632.70	43.18	120.89	0.28	0.46	1.99	0.00
p910-913+915-85 AVERAGE	154.68	245.74	33.50	48.48	2.79	0.03	1436.25	31.64	118.30	0.32	0.80	1.12	0.00
p910-913+915-87 AVERAGE	182.57	130.91	86.00	4.07	2.43	0.01	2751.99	27.08	112.91	0.33	0.64	1.45	0.00
p910-913+915-90 AVERAGE	165.43	176.38	45.66	35.52	2.60	0.03	1673.56	24.53	120.47	0.33	0.87	1.22	0.00
p910-913+915-96 AVERAGE	143.54	240.16	53.66	39.48	1.78	0.03	2650.65	27.89	119.84	0.26	0.79	1.50	0.00

p910-913+915-97 AVERAGE	93.46	382.10	5.30	20.61	1.12	0.01	82.25	21.83	106.01	0.19	1.77	0.16	0.00
UA2012-83 P910-2 AVERAGE	131.49	229.95	38.22	0.00	1.13	0.00	446.41	39.93	120.55	0.22	0.61	0.67	0.00
UA2012-83 P899-1 AVERAGE	155.11	249.56	22.07	69.72	4.77	0.08	1082.15	23.80	105.09	0.25	0.69	0.69	0.00
UA2012-83 P916-1 AVERAGE	142.55	278.22	42.42	44.24	2.61	0.04	2513.16	19.62	115.35	0.22	0.79	1.27	0.00
UA2012-83 P813-3 AVERAGE	179.69	376.82	49.39	61.96	4.16	0.08	2577.70	45.80	143.06	0.28	0.95	1.54	0.00
UA2012-83 P813-10 AVERAGE	50.72	38.34	3.00	9.12	0.26	0.00	189.24	15.30	50.01	0.08	0.11	0.07	0.00
UA2012-83 P813-28 AVERAGE	60.54	22.65	13.49	0.00	0.09	0.00	327.64	50.24	82.16	0.13	0.19	0.39	0.00
UA2012-83 P813-48 AVERAGE	132.40	163.07	70.75	40.46	2.44	0.05	3527.51	49.02	163.90	0.19	0.46	2.26	0.00
UA2012-83 P813-49 AVERAGE	150.60	189.16	61.64	38.24	2.88	0.03	2698.70	53.02	148.35	0.32	0.81	1.84	0.00
UA2012-83 P813-51 AVERAGE	254.56	552.51	48.57	80.58	4.66	0.13	2110.32	51.10	163.42	0.25	0.88	1.49	0.00
UA2012-83 P813-53 AVERAGE	139.49	368.72	10.07	61.31	4.12	0.04	88.48	36.72	103.69	0.26	1.14	0.18	0.00
UA2012-83 P813-56 AVERAGE	64.86	22.79	12.96	0.00	0.09	0.00	267.84	57.14	129.59	0.08	0.20	0.22	0.00
UA2012-83 P813-91 AVERAGE	73.27	49.68	5.33	0.00	0.10	0.00	143.84	49.13	107.60	0.19	0.19	0.16	0.00
UA2012-83 P813-92 AVERAGE	90.31	65.61	7.64	13.09	0.14	0.00	0.00	50.56	119.80	0.16	0.19	0.16	0.00
UA2012-83 P813-128 AVERAGE	61.48	47.30	7.56	0.00	0.08	0.00	0.00	56.07	78.90	0.18	0.16	0.11	0.00
UA2012-83 P813-145 AVERAGE	147.67	360.87	42.53	58.46	4.44	0.09	2391.10	36.09	145.50	0.23	0.96	1.39	0.00
UA2012-83 P813-147 AVERAGE	116.71	307.67	47.34	52.95	3.16	0.09	2842.52	36.30	140.46	0.16	0.60	1.69	0.00
UA2012-83 P813-163 AVERAGE	67.92	39.69	7.03	4.20	0.06	0.00	494.79	21.48	78.24	0.08	0.12	0.17	0.00
UA2012-83 P813-165 AVERAGE	82.40	46.76	10.13	6.11	0.21	0.00	45.49	53.50	83.20	0.08	0.18	0.21	0.00
UA2012-83 P813-204 AVERAGE	75.79	42.32	17.42	0.00	0.12	0.00	2366.72	37.66	127.74	0.08	0.16	0.30	0.00
UA2012-83 P813-205 AVERAGE	179.91	118.56	23.48	0.00	0.26	0.02	347.05	80.74	197.74	0.14	0.15	0.24	120.28
UA2012-83 P813-150 AVERAGE	123.59	285.19	37.31	47.17	3.49	0.07	2895.51	20.05	119.01	0.20	0.81	1.36	0.00
UA2012-83 P813-153 AVERAGE	270.56	279.08	77.61	52.33	1.70	0.04	2589.22	66.47	196.06	0.31	0.68	2.30	0.00
UA2012-83 P813-247 AVERAGE	303.04	226.24	112.73	76.57	2.47	0.09	3373.95	64.40	192.65	0.20	0.34	3.48	0.00

UA2012-83 P813-265 AVERAGE	225.01	239.94	62.11	50.21	2.50	0.02	2274.42	39.34	145.15	0.37	0.97	1.63	0.00
UA2012-83 P813-268 AVERAGE	157.76	259.61	70.04	45.29	2.83	0.05	2852.88	54.74	189.72	0.30	0.57	2.65	0.00
UA2012-83 AMU-2-3213 AVERAGE	58.34	33.16	5.98	10.73	0.07	0.00	0.00	43.27	109.20	0.10	0.22	0.11	0.00
UA2012-83 AMU-2-4564 AVERAGE	54.90	38.69	0.00	4.54	0.10	0.00	276.44	15.03	69.37	0.09	0.12	0.11	0.00
UA2012-83 AMU-2-4502 AVERAGE	141.96	161.47	29.68	39.64	2.67	0.03	1508.08	33.25	99.33	0.25	0.63	0.94	0.00
UA2012-83 AMU-2-4504 AVERAGE	138.53	270.07	58.59	63.09	3.27	0.09	2205.29	34.82	133.43	0.18	0.84	1.79	0.00
UA2012-83 AMU-2-4505 AVERAGE	78.44	40.06	32.15	5.12	0.29	0.01	2395.45	14.38	101.08	0.11	0.21	0.50	0.00
UA2012-83 P700-3085-33 AVERAGE	174.95	205.17	39.84	49.82	3.64	0.05	1536.41	40.93	142.10	0.29	0.72	1.13	0.00
UA2012-83 P700-3085-26 AVERAGE	110.25	396.16	9.93	53.21	2.42	0.04	1611.82	18.23	95.87	0.17	0.74	0.39	0.00
UA2012-83 P700-3085-32 AVERAGE	154.03	148.45	39.48	11.27	1.45	0.01	1863.59	34.30	103.53	0.27	0.92	1.13	0.00
UA2012-83 P700-3085-47 AVERAGE	123.66	64.51	10.46	0.00	0.08	0.00	0.00	57.76	83.38	0.13	0.18	0.14	0.00
UA2012-83 P708-3085-17 AVERAGE	115.22	294.29	35.81	48.41	2.53	0.08	3005.69	18.59	123.23	0.17	0.66	1.18	340.24
UA2012-83 P857/858-3056 AVERAGE	39.60	62.98	3.34	19.18	0.31	0.00	413.24	3.94	47.08	0.06	0.17	0.17	0.00
UA2012-83 P813-2 AVERAGE	58.14	46.93	1.21	4.85	0.08	0.00	176.34	15.83	44.84	0.09	0.12	0.12	0.00
UA2012-83 P813-155 AVERAGE	66.22	41.26	5.87	10.34	0.15	0.00	88.95	26.91	52.28	0.10	0.15	0.20	0.00
UA2012-83 P813-164 AVERAGE	66.51	32.58	6.97	15.55	0.16	0.00	101.71	45.38	68.50	0.08	0.13	0.10	0.00
UA2012-83 P813-224 AVERAGE	57.39	38.83	6.84	4.44	0.12	0.00	97.21	36.23	122.57	0.10	0.14	0.12	0.00
UA2012-83 P813-162 AVERAGE	71.51	38.84	6.73	0.00	0.08	0.00	84.63	29.40	85.09	0.10	0.14	0.16	0.00
UA2012-59-967-36 (#2109.1-36) AVERAGE	210.83	120.85	37.45	23.02	2.05	0.04	244.09	74.29	100.04	0.11	0.47	1.87	0.00
UA2012-83 P839/852-4500 AVERAGE	126.87	190.01	2.17	8.48	0.92	0.00	178.04	14.02	89.79	0.12	1.24	0.09	0.00
UA2012-83 P813-9 AVERAGE	43.87	32.75	11.42	27.03	0.42	0.02	7545.21	13.48	96.48	0.09	0.14	0.34	0.00
UA2012-83 P813-22 AVERAGE	93.72	29.55	17.60	0.00	0.21	0.00	284.25	72.07	115.91	0.10	0.25	0.30	117.55
UA2012-83 P813-138 AVERAGE	47.58	45.62	8.32	3.43	0.11	0.01	1558.16	19.00	26.58	0.06	0.21	0.14	106.71
UA2012-83 P813-1 AVERAGE	166.18	174.00	41.15	33.86	2.48	0.03	2764.91	30.08	124.34	0.30	0.64	1.31	0.00

UA2012-83 P813-142 AVERAGE	263.81	511.18	74.83	102.22	4.47	0.23	2713.09	66.88	190.35	0.19	0.89	2.11	0.00
UA2012-83 P813-8 AVERAGE	166.36	244.45	14.12	23.23	1.38	0.01	375.61	34.63	97.41	0.26	1.67	0.41	0.00
UA2012-83 P700-26 AVERAGE	184.45	367.50	24.49	79.78	3.79	0.08	1125.85	59.08	148.96	0.25	1.05	0.72	0.00
UA2012-83 P813-220 AVERAGE	127.90	244.58	44.59	46.71	1.76	0.03	1755.32	34.10	130.91	0.17	1.39	1.63	0.00
UA2012-83 P839/852-4514 AVERAGE	45.46	56.42	24.61	25.96	1.77	0.00	935.05	10.77	63.73	0.20	0.22	0.31	0.00
UA2012-83 P814-3 AVERAGE	63.35	54.50	24.04	4.37	0.19	0.00	412.06	52.26	168.07	0.05	0.18	0.24	0.00
UA91-079-1044 AVERAGE	87.29	47.88	20.51	38.75	2.44	0.11	1120.96	24.50	84.70	0.14	0.17	0.33	0.00
UA2012-59-598 (1773) AVERAGE	139.77	262.03	87.04	48.27	1.09	0.03	6067.45	59.69	329.27	0.10	0.28	1.61	0.00
UA2012-59-608 (1783) AVERAGE	69.59	110.29	18.24	38.85	1.16	0.05	4510.12	37.30	174.74	0.00	0.26	0.31	216.12
UA2012-59-974 (2112.2) AVERAGE	188.11	37.78	168.96	99.58	1.80	0.01	897.90	43.77	126.46	0.16	0.18	3.93	0.00
UA2012-59-636 (1811) AVERAGE	86.35	20.18	44.51	26.42	0.32	0.01	281.97	14.24	89.46	0.10	0.39	0.62	0.00
UA2012-59-1148-17 (2249.2-17) AVERAGE	383.67	575.78	67.51	42.15	1.28	0.04	434.25	76.73	45.10	0.14	0.97	3.34	218.73
P813-4 AVERAGE	79.19	39.35	7.72	6.71	0.06	0.00	0.00	51.51	0.00	0.07	0.05	0.11	324.85
P813-11 AVERAGE	79.96	31.84	8.68	0.00	0.10	0.00	234.30	34.16	0.00	0.09	0.10	0.18	145.96
P813-13 AVERAGE	65.35	33.82	5.89	0.00	0.12	0.00	117.61	21.38	0.00	0.08	0.04	0.10	0.00
P813-21 AVERAGE	176.64	379.07	40.70	53.56	3.43	0.14	4631.71	21.06	136.04	0.21	0.88	1.58	0.00
P813-18 AVERAGE	303.48	436.95	88.21	16.47	1.94	0.06	3113.83	72.12	176.37	0.23	0.85	2.67	0.00
P813-94 AVERAGE	72.50	32.67	6.82	0.00	0.06	0.00	134.60	34.86	0.00	0.09	0.04	0.14	0.00
P813-131 AVERAGE	49.78	29.54	8.03	0.00	0.07	0.00	73.00	55.20	0.00	0.06	0.04	0.15	0.00
P813-146 AVERAGE	154.93	388.93	55.67	89.69	3.59	0.12	2677.87	43.18	146.26	0.14	0.39	2.11	0.00
P813-149 AVERAGE	155.73	320.52	34.76	52.74	3.88	0.08	2559.72	28.50	132.01	0.22	0.84	1.21	0.00
P813-152 AVERAGE	365.74	259.77	67.83	65.52	3.22	0.13	1814.20	75.27	185.48	0.23	0.34	1.98	0.00
P813-163 AVERAGE	84.01	37.30	4.86	0.00	0.06	0.00	249.93	38.24	0.00	0.08	0.03	0.15	0.00
P813-166 AVERAGE	71.39	29.52	3.95	0.00	0.03	0.00	101.22	27.03	0.00	0.07	0.03	0.14	337.65

P813-203 AVERAGE	99.15	89.75	15.25	24.00	1.51	0.07	873.92	51.88	120.73	0.13	0.05	0.24	262.40
P813-204 AVERAGE	74.04	38.78	17.04	0.00	0.13	0.00	2720.89	33.08	126.88	0.07	0.04	0.26	327.97
P813-219 AVERAGE	72.72	31.64	2.99	30.34	1.54	0.00	682.23	12.71	21.31	0.12	0.14	0.17	0.00
P813-244 AVERAGE	163.12	189.45	74.53	21.65	1.95	0.02	3078.08	57.49	153.69	0.27	0.76	2.51	0.00
P813-245 AVERAGE	192.65	284.97	54.05	46.73	2.83	0.06	2073.32	54.42	162.42	0.24	1.20	1.94	0.00
P813-257 AVERAGE	85.65	35.72	2.29	0.00	0.08	0.00	117.82	40.32	0.00	0.11	0.06	0.22	613.08
P813-260 AVERAGE	102.59	48.01	9.14	0.00	0.07	0.00	56.64	58.77	0.00	0.07	0.03	0.13	152.08
P813-272 AVERAGE	388.45	301.21	100.07	66.83	2.48	0.08	2152.67	70.92	158.10	0.23	0.35	2.94	0.00
P712-2 (67-2-3085-2) AVERAGE	119.15	284.01	47.75	42.96	3.20	0.09	2650.07	35.46	144.16	0.17	0.49	1.69	0.00
67-2-4503 AVERAGE	142.50	299.09	40.74	34.92	2.15	0.03	2080.92	32.45	108.95	0.23	0.80	1.53	0.00
P711-5 AVERAGE	159.66	194.10	37.90	49.09	3.39	0.04	1662.60	40.32	128.51	0.32	0.69	1.27	0.00
UA2012-59-669-22 AVERAGE	882.45	372.10	132.79	100.87	3.09	0.07	425.79	56.24	56.60	0.23	1.66	3.34	0.00
UA2012-59-669-23 AVERAGE	393.64	527.63	53.21	157.09	4.64	0.16	441.12	47.06	70.92	0.33	3.10	1.34	439.71
UA2012-59-669-25 AVERAGE	373.83	480.40	47.40	142.15	4.44	0.14	483.28	35.79	22.28	0.34	2.96	1.28	460.12
UA2012-59-669-27 AVERAGE	71.24	94.31	37.56	29.61	1.49	0.03	798.24	30.29	119.96	0.09	0.18	0.59	0.00
UA2012-59-669-28 AVERAGE	279.50	259.18	181.08	104.39	4.81	0.02	1208.97	48.82	230.27	0.49	0.17	3.91	0.00
UA2012-59-669-72 AVERAGE	81.26	208.51	34.92	67.11	2.48	0.06	5888.73	23.24	112.49	0.12	0.10	0.53	271.56
UA2012-59-669-130 AVERAGE	43.38	29.24	11.07	24.79	0.69	0.03	2224.48	27.91	78.35	0.01	0.12	0.26	253.02
UA2012-59-669-147 AVERAGE	347.23	57.36	443.99	460.22	3.28	0.11	811.87	85.65	166.60	0.16	0.14	5.43	0.00
UA2012-59-669-144 AVERAGE	283.50	444.82	58.30	71.59	3.07	0.06	444.17	28.03	41.19	0.21	2.05	1.46	349.04
UA2012-59-669-986-6 AVERAGE	65.61	87.09	10.86	19.65	1.05	0.04	3604.32	39.74	143.59	0.00	0.08	0.21	0.00
UA2012-59-669-967-26 AVERAGE	498.97	616.36	67.44	200.53	5.36	0.18	383.73	64.61	46.55	0.31	3.43	1.89	0.00
UA2012-59-669-986-48 AVERAGE	99.41	104.72	23.41	6.85	0.98	0.02	4510.04	40.80	196.82	0.02	0.08	0.36	176.86
UA2012-59-669-1151-12 AVERAGE	109.02	151.39	75.57	43.05	2.63	0.04	2186.50	32.62	99.96	0.10	0.15	1.65	0.00

UA2012-59-669-1151-13 AVERAGE	491.68	378.61	72.95	104.83	3.75	0.09	987.44	34.71	55.71	0.18	1.91	2.28	0.00
UA2012-59-669-1148-3 AVERAGE	111.82	129.03	44.66	27.66	1.08	0.02	1012.50	53.44	153.57	0.08	0.06	1.04	0.00
UA2012-59-669-1148-5 AVERAGE	527.35	693.31	72.02	232.41	6.03	0.19	281.77	72.99	0.00	0.32	3.69	1.70	0.00
UA2012-59-669-1152-1 AVERAGE	48.00	15.10	45.27	0.00	0.15	0.00	792.29	35.18	77.62	0.04	0.09	0.52	262.95
UA80-181-60-21 AVERAGE	73.81	34.23	12.09	15.51	1.21	0.04	711.11	25.91	79.39	0.15	0.03	0.18	0.00
UA80-181-60-22 AVERAGE	145.15	723.29	40.84	28.84	2.68	0.06	2872.67	33.95	120.93	0.15	2.44	1.74	0.00
UA80-181-60-59 AVERAGE	163.23	340.92	22.74	44.19	3.57	0.07	2125.44	19.36	112.41	0.19	0.81	0.89	0.00
UA80-181-60-83 AVERAGE	147.37	275.58	22.74	49.14	4.15	0.07	1360.43	22.26	104.99	0.27	0.62	0.77	384.23
UA80-181-60-85 AVERAGE	323.60	413.70	60.36	79.32	5.33	0.16	2036.61	56.66	145.32	0.19	0.81	2.00	382.49
UA80-181-60-101 AVERAGE	82.14	49.13	18.37	43.49	2.43	0.10	1860.22	13.42	74.21	0.14	0.12	0.50	713.32
UA80-181-60-118 AVERAGE	135.91	277.37	24.56	48.58	3.13	0.05	2181.58	22.43	111.29	0.23	0.60	0.89	0.00
UA80-181-60-125 AVERAGE	129.15	232.67	40.79	44.52	3.04	0.07	3072.20	21.20	130.59	0.26	0.68	1.18	0.00
UA80-181-60-128 AVERAGE	119.12	49.67	41.27	25.95	2.84	0.06	1802.60	38.62	107.51	0.35	0.13	0.54	0.00
UA80-181-60-171 AVERAGE	99.08	40.69	31.13	29.23	1.67	0.06	1485.63	31.19	92.99	0.11	0.02	0.37	0.00
UA80-181-60-189 AVERAGE	77.94	46.24	14.31	22.24	0.83	0.03	687.72	34.49	108.72	0.14	0.04	0.28	0.00
UA80-181-60-215 AVERAGE	95.78	53.81	53.12	18.68	1.44	0.04	2063.06	46.82	141.87	0.14	0.05	0.52	200.90
UA80-181-60-241 AVERAGE	168.03	139.58	31.58	46.72	2.89	0.02	1269.72	42.46	99.55	0.22	0.36	1.15	0.00
UA80-181-60-251 AVERAGE	77.61	24.60	13.48	0.00	0.11	0.00	529.78	26.26	0.00	0.12	0.07	0.15	0.00
UA80-181-60-301 AVERAGE	72.25	35.60	45.50	0.00	0.15	0.02	1570.10	49.60	136.08	0.10	0.07	0.41	0.00
UA2012-83 P899-P903-7 AVERAGE	163.37	192.07	31.34	73.05	3.43	0.03	1055.73	50.54	117.66	0.30	0.80	1.05	0.00
UA2012-83 P899-P903-8 AVERAGE	139.51	174.95	45.93	45.27	2.41	0.04	2597.95	18.57	100.98	0.25	0.45	1.28	0.00
UA2012-83 P899-P903-9 AVERAGE	152.76	255.53	31.81	35.81	3.39	0.04	1126.82	32.55	110.51	0.25	0.71	0.87	0.00
UA2012-83 P899, 900, 902, 903-40 AVERAGE	162.42	209.66	41.83	38.57	2.47	0.02	2241.74	36.01	119.66	0.29	0.61	1.41	0.00
UA2012-83 P899, 900, 902, 903-42 AVERAGE	266.86	255.44	101.53	69.48	3.71	0.14	3372.08	63.29	191.84	0.25	0.36	2.85	0.00

UA2012-83 P899, 900, 902, 903-44 AVERAGE	398.98	212.68	42.03	52.32	3.07	0.07	720.27	77.60	164.87	0.53	0.93	1.07	0.00
UA2012-83 P916-919-64 AVERAGE	126.03	316.19	37.37	38.96	1.89	0.06	3937.52	15.90	116.65	0.22	0.57	1.36	0.00
UA2012-83 P916-919-68 AVERAGE	159.81	287.54	26.56	59.50	3.41	0.05	1726.35	20.12	112.82	0.31	0.75	0.93	0.00
UA2012-83 P916-919-38 AVERAGE	149.14	335.67	23.52	87.38	4.81	0.09	1034.18	35.54	118.30	0.25	0.96	0.80	0.00
UA2012-83 P916-919-35 AVERAGE	443.41	427.89	54.51	45.64	2.30	0.03	1400.32	64.06	148.31	0.72	0.95	1.83	307.05
UA2012-83 P916-919-34 AVERAGE	369.03	312.83	51.35	75.17	3.67	0.07	1195.73	67.87	141.67	0.29	0.92	1.57	0.00
UA2012-83 P916-919-29 AVERAGE	498.88	434.92	48.58	80.61	4.58	0.09	1002.97	82.40	168.44	0.33	1.19	1.48	0.00
UA2012-83 P910-913+915-42 AVERAGE	120.03	46.79	11.04	0.00	0.09	0.00	66.07	62.05	0.00	0.05	0.04	0.10	0.00
UA2012-83 P910-913+915-12 AVERAGE	366.65	330.59	124.23	35.83	2.64	0.08	2900.03	85.85	207.64	0.25	1.06	3.97	0.00
UA2012-83 P908-6 AVERAGE	123.65	167.48	39.84	35.31	2.16	0.03	1860.41	27.00	102.07	0.23	0.57	1.09	0.00
LMG 1 upper-1 mean	104.55	250.34	48.38	29.95	2.86	0.04	1563.18	11.79	93.93	0.16	0.66	0.90	#NULL!
LMG 1 upper-2 mean	137.60	253.46	64.23	38.64	3.14	0.05	1816.34	15.09	108.57	0.21	0.63	1.20	#NULL!
LMG 10 upper-1 mean	101.66	377.49	20.26	32.78	2.70	0.05	2952.92	12.28	101.18	0.16	0.93	0.66	#NULL!
LMG 10 upper-2 mean	166.24	552.44	10.84	50.55	2.69	0.04	1517.26	17.26	106.85	0.18	0.93	0.27	#NULL!
LMG 10 upper-3 mean	161.56	613.76	9.99	#NULL!	2.47	0.04	1364.82	17.92	92.89	0.18	1.25	0.24	#NULL!
LMG 10 upper-4 mean	106.69	365.05	17.67	37.50	2.92	0.05	2447.54	11.77	98.43	0.16	1.29	0.62	#NULL!
LMG 10 upper-5 mean	108.14	425.13	27.10	31.64	#NULL!	0.03	1655.16	20.43	#NULL!	0.13	0.88	0.94	#NULL!
LMG 10 upper-6 mean	110.21	393.55	25.23	26.74	#NULL!	0.03	1896.57	14.39	103.88	0.11	1.43	0.82	#NULL!
LMG 10B-1 mean	108.77	326.13	5.51	37.08	2.87	0.05	664.23	13.42	72.17	0.17	1.29	0.12	#NULL!
LMG 10B-2 mean	111.42	218.89	5.85	36.88	3.02	0.05	395.27	15.05	73.06	0.16	1.01	0.10	#NULL!
LMG 11-1 mean	153.14	297.92	#NULL!	42.44	2.70	0.05	275.11	17.32	76.13	0.18	1.24	0.04	#NULL!
LMG 11-2 mean	99.21	213.70	#NULL!	#NULL!	3.76	0.07	307.85	10.70	64.80	0.19	0.81	0.07	#NULL!

LMG 11-3 mean	113.04	507.32	7.65	39.88	2.81	0.04	1266.88	14.72	83.75	0.17	0.67	0.12	#NULL!
LMG 11-4 mean	97.06	216.76	3.47	#NULL!	3.45	0.06	291.60	10.49	76.20	0.18	1.14	0.06	#NULL!
LMG 11-5 mean	157.32	312.52	4.10	42.28	2.63	0.05	307.95	19.04	81.98	0.19	0.65	0.06	#NULL!
LMG 11-6 mean	100.40	219.03	3.16	#NULL!	3.33	0.07	295.68	11.70	75.56	0.16	0.86	#NULL!	#NULL!
LMG 12-1 mean	159.03	312.89	48.22	31.18	2.85	0.02	1067.18	17.61	74.28	0.21	0.62	0.84	#NULL!
LMG 12-2 mean	210.85	489.58	6.19	25.89	2.29	0.02	444.86	21.92	81.64	0.16	0.90	0.08	#NULL!
LMG 12-3 mean	205.56	497.21	6.01	30.54	2.33	0.03	474.68	22.60	77.46	0.17	1.13	0.10	#NULL!
LMG 12-4 mean	171.40	320.11	50.80	36.34	2.77	0.02	1125.45	19.37	103.58	0.21	1.07	0.91	#NULL!
LMG 12-5 mean	231.06	490.32	#NULL!	40.02	2.71	0.03	452.38	23.47	80.94	0.15	0.94	0.05	750.97
LMG 12-6 mean	239.78	495.66	#NULL!	33.55	2.81	0.03	463.84	21.01	77.21	0.16	1.04	0.07	#NULL!
LMG 13-1 mean	164.69	568.75	11.49	33.59	3.38	0.04	1346.10	17.16	105.07	0.19	1.05	0.40	#NULL!
LMG 13-2 mean	141.44	401.88	6.20	43.66	#NULL!	0.05	496.27	16.65	75.77	0.22	1.30	0.16	#NULL!
LMG 13-3 mean	121.17	476.71	5.30	38.94	2.91	0.03	492.46	11.88	81.37	0.18	1.19	0.18	835.22
LMG 13-4 mean	117.94	494.17	5.40	33.71	2.91	0.03	455.80	12.78	69.54	0.17	1.21	0.10	#NULL!
LMG 13-5 mean	146.14	404.76	7.04	38.74	3.72	0.06	627.21	18.10	92.10	0.22	1.23	0.23	#NULL!
LMG 13-6 mean	145.97	394.21	6.14	42.21	3.49	0.06	663.04	18.46	80.07	0.20	1.24	0.19	#NULL!
LMG 14-1 mean	113.91	248.31	7.84	36.01	3.39	0.04	720.69	11.98	79.18	0.15	0.76	0.28	#NULL!
LMG 14-2 mean	135.38	319.31	8.94	33.02	3.71	0.05	584.74	15.02	79.24	0.17	0.65	0.23	#NULL!
LMG 14-3 mean	110.67	195.09	4.55	33.44	3.56	0.05	350.86	14.31	74.51	0.17	0.75	0.10	#NULL!
LMG 14-4 mean	131.96	331.31	6.85	32.76	3.53	0.05	553.87	18.25	89.32	0.16	0.63	0.19	#NULL!
LMG 14-5 mean	111.38	247.70	7.62	27.70	3.35	0.04	670.73	12.20	82.32	0.17	0.80	0.31	#NULL!

LMG 14-6 mean	127.69	370.47	11.83	21.45	2.94	0.04	768.06	16.99	87.50	0.17	#NULL!	0.35	#NULL!
LMG 14-7 mean	146.81	#NULL!	3.46	#NULL!	3.22	0.06	264.57	17.35	58.90	0.14	0.63	0.03	#NULL!
LMG 14-8 mean	#NULL!	#NULL!	9.75	32.48	3.20	0.07	567.60	27.26	#NULL!	0.23	0.82	0.26	#NULL!
LMG 15-1 mean	199.91	332.82	37.87	36.15	2.63	0.02	1071.22	21.23	86.03	0.17	1.21	0.75	#NULL!
LMG 15-2 mean	115.61	258.05	36.21	34.40	2.51	0.02	1001.76	15.28	80.84	0.15	1.01	0.73	#NULL!
LMG 15-3 mean	149.51	240.97	44.79	36.62	2.62	0.02	1300.98	17.33	91.00	0.17	0.75	0.93	#NULL!
LMG 15-4 mean	144.65	250.90	48.67	32.45	2.61	0.02	1284.65	18.71	98.60	0.17	0.74	0.92	#NULL!
LMG 15-5 mean	205.52	497.84	4.16	33.45	2.96	0.03	480.02	25.80	80.52	0.18	0.76	0.07	#NULL!
LMG 15-6 mean	131.44	269.03	37.34	33.81	2.53	0.02	993.91	16.83	81.11	0.14	1.31	0.71	#NULL!
LMG 2 upper-1 mean	121.30	394.31	13.41	41.85	3.18	0.05	1940.90	11.49	101.39	0.18	0.98	0.42	#NULL!
LMG 2 upper-2 mean	103.08	386.29	12.71	31.97	2.88	0.04	2074.83	13.98	79.31	0.17	0.99	0.42	#NULL!
LMG 3-1 mean	124.94	263.97	62.47	32.45	3.30	0.04	1662.36	11.49	83.15	0.19	1.26	1.23	#NULL!
LMG 3-2 mean	126.36	267.09	59.85	28.54	3.19	0.05	1724.43	16.09	86.52	0.19	0.66	1.20	#NULL!
LMG 4-1 mean	137.03	368.72	26.13	42.04	2.79	0.06	2372.35	13.63	90.06	0.15	#NULL!	0.87	#NULL!
LMG 4-2 mean	213.47	462.13	28.46	29.75	2.55	0.05	2327.43	24.58	69.59	0.15	0.93	0.86	#NULL!
LMG 4-3 mean	242.31	454.34	68.40	46.42	3.12	0.07	2547.74	25.25	#NULL!	0.22	0.61	1.43	#NULL!
LMG 4-4 mean	207.62	409.62	39.33	32.00	2.55	0.05	2033.88	24.96	91.90	0.15	1.08	0.90	647.59
LMG 4-5 mean	167.78	357.90	27.31	43.96	2.97	0.06	2407.01	17.16	101.83	0.19	1.01	0.89	#NULL!
LMG 4-6 mean	237.29	425.03	45.59	29.76	2.43	0.05	2135.22	#NULL!	94.00	0.15	0.98	1.00	#NULL!
LMG 5-1 mean	164.38	364.37	38.52	38.59	3.32	0.08	1665.55	14.19	94.71	0.22	1.12	0.79	#NULL!
LMG 5u mean	126.38	315.75	39.85	27.94	2.89	0.06	2156.84	14.04	99.45	0.16	0.94	0.87	#NULL!

LMG 6-1 mean	112.61	326.40	39.30	47.25	3.10	0.06	2468.27	14.58	96.97	0.16	0.87	0.97	#NULL!
LMG 6-2 mean	169.62	181.14	#NULL!	37.18	2.69	0.04	233.55	21.26	79.36	0.21	0.80	0.03	#NULL!
LMG 7-1 mean	134.77	321.44	32.64	49.29	2.68	0.05	2430.11	13.44	86.11	0.17	1.11	1.04	#NULL!
LMG 7-2 mean	112.25	283.19	26.34	48.22	2.83	0.07	2181.28	13.27	98.83	0.16	0.89	0.88	#NULL!
LMG 8 low-1 mean	116.55	274.04	55.84	33.84	2.54	0.05	1890.17	13.19	93.95	0.17	0.64	1.09	#NULL!
LMG 8 low-2 mean	117.82	367.23	9.00	30.97	2.15	0.03	2204.41	13.06	84.64	0.14	0.70	0.28	#NULL!
LMG 8 upper mean	119.21	339.77	20.56	36.40	3.08	0.05	1784.46	11.67	94.41	0.15	0.67	0.52	#NULL!
LMG 8 west-1 mean	189.67	197.94	64.28	29.01	2.91	0.04	2658.75	21.39	101.89	0.22	0.90	1.26	#NULL!
LMG 8 west-2 mean	186.38	179.56	63.93	26.60	2.74	0.04	3039.91	22.90	98.59	0.21	0.67	1.23	#NULL!
LMG 9-1 mean	127.27	307.50	#NULL!	29.16	2.40	0.03	391.01	15.15	73.48	0.15	0.60	#NULL!	#NULL!
LMG 9-2 mean	129.52	344.91	3.90	50.15	2.96	0.04	549.41	15.51	81.04	0.16	0.68	#NULL!	#NULL!
LL 10C-1 mean	65.70	272.79	28.67	63.93	1.87	0.10	7071.98	7.73	99.47	0.07	0.06	0.45	#NULL!
LL 10C-5 mean	63.67	272.39	20.55	56.17	1.57	0.09	6787.91	7.09	91.62	0.07	0.13	0.37	764.14
LL 10C-6 mean	56.49	241.54	15.34	49.82	1.32	0.04	6319.54	9.17	90.36	0.05	0.13	0.22	#NULL!
LL 10N-2 mean	57.49	230.63	21.38	66.88	1.72	0.08	7432.05	6.91	96.55	0.05	0.12	0.34	877.58
LL 10S-4 mean	69.72	227.27	19.46	55.07	1.86	0.07	6728.09	8.50	93.55	0.07	0.14	0.33	#NULL!
LL 1-1 mean	75.50	132.86	20.71	67.64	1.76	0.07	1649.87	8.42	66.55	0.13	#NULL!	0.40	5359.43
LL 11-1 mean	65.14	174.66	31.74	72.90	2.08	0.07	5891.93	7.32	95.27	0.08	0.06	0.52	738.04
LL 11-2 mean	64.57	153.54	31.80	56.74	1.33	0.05	5096.94	7.01	81.14	0.07	0.09	0.48	#NULL!
LL 11-3 mean	66.95	254.61	24.37	42.82	1.12	0.04	7200.61	7.09	99.35	0.06	0.08	0.34	#NULL!
LL 11-4 mean	66.75	173.28	31.09	64.12	2.18	0.08	6891.57	7.07	102.34	0.08	0.08	0.50	#NULL!
LL 11-5 mean	64.96	221.27	26.12	69.26	1.50	0.07	7745.58	7.51	95.26	0.08	0.08	0.42	684.11

LL 11-6 mean	59.09	162.14	24.43	74.59	1.78	0.08	5862.94	11.29	93.36	0.05	0.09	0.39	6543.43
LL 1-2 mean	71.06	96.35	28.25	76.23	1.79	0.07	2213.91	7.91	64.15	0.10	0.14	0.54	13270.39
LL 12-1 mean	74.68	#NULL!	21.28	58.19	1.76	0.08	#NULL!	9.33	115.16	0.07	#NULL!	0.38	1127.75
LL 12-2 mean	73.46	244.42	20.86	58.86	1.86	0.06	6906.88	9.15	104.53	0.07	#NULL!	0.29	#NULL!
LL 12-3 mean	78.56	244.58	26.86	54.13	1.87	0.06	6506.24	9.66	103.82	0.09	0.13	0.40	#NULL!
LL 12-4 mean	67.97	189.81	31.59	49.35	1.48	0.06	6254.19	7.63	106.17	0.09	0.15	0.45	#NULL!
LL 12-5 mean	76.89	167.56	21.14	66.58	2.43	0.06	3135.98	8.89	81.08	0.10	0.08	0.41	8748.20
LL 12-6 mean	79.16	166.28	21.29	77.12	2.38	0.06	3261.26	9.21	95.11	0.10	0.14	0.37	#NULL!
LL 13-1 mean	59.92	#NULL!	18.18	44.11	1.14	0.04	#NULL!	8.62	116.97	0.05	0.09	0.30	1132.02
LL 13-2 mean	88.66	250.86	20.09	57.53	1.75	0.06	2844.30	11.80	82.36	0.11	0.09	0.30	#NULL!
LL 13-3 mean	67.39	196.78	21.36	56.96	1.46	0.06	3726.57	7.66	81.92	0.08	#NULL!	0.35	#NULL!
LL 13-4 mean	77.08	287.58	17.41	46.09	1.46	0.05	2569.51	8.94	85.45	0.10	#NULL!	0.24	#NULL!
LL 13-5 mean	66.11	134.80	30.22	67.51	1.84	0.06	3084.48	9.14	90.75	0.08	#NULL!	0.51	#NULL!
LL 13-6 mean	65.28	197.02	23.65	52.84	1.52	0.04	4561.53	7.71	94.65	0.08	0.13	0.38	#NULL!
LL 14-1 mean	69.32	186.41	23.49	47.09	1.45	0.05	5704.74	8.35	93.60	0.08	#NULL!	0.38	#NULL!
LL 14-2 mean	72.31	215.73	25.55	53.58	1.75	0.07	7099.06	10.26	98.98	0.07	0.07	0.41	#NULL!
LL 14-3 mean	64.32	147.46	31.16	33.27	0.84	0.02	3552.29	8.22	99.17	0.09	0.07	0.52	9534.50
LL 14-4 mean	71.87	267.40	26.08	53.20	1.63	0.06	8397.30	9.59	113.18	0.08	0.09	0.42	697.32
LL 14-5 mean	66.33	145.10	32.10	40.10	0.70	0.02	3708.62	11.24	101.77	0.09	0.07	0.52	1195.29
LL 14-6 mean	63.42	177.70	27.29	48.78	1.31	0.04	4885.55	8.12	100.71	0.08	0.08	0.41	#NULL!

LL 15-1 mean	#NULL!	279.60	33.20	62.52	1.92	0.06	5911.42	10.72	129.87	0.15	0.10	0.62	653.96
LL 15-2 mean	#NULL!	343.57	#NULL!	60.00	2.41	0.09	11094.94	#NULL!	#NULL!	#NULL!	0.10	#NULL!	#NULL!
LL 16-1 mean	77.54	135.41	30.05	51.61	1.39	0.03	3547.55	10.06	97.34	0.09	0.11	0.46	#NULL!
LL 16-2 mean	75.65	96.31	25.80	87.64	1.77	0.05	3507.86	8.53	96.68	0.11	0.07	0.46	#NULL!
LL 16-3 mean	70.04	136.81	34.03	42.20	1.13	0.03	5117.64	10.06	111.65	0.10	0.05	0.57	#NULL!
LL 16-4 mean	70.03	152.64	32.91	49.07	1.11	0.02	5175.77	8.07	111.60	0.09	0.05	0.52	#NULL!
LL 16-5 mean	73.70	132.60	26.66	49.86	1.13	0.03	3315.63	11.38	101.51	0.08	0.06	0.43	11340.63
LL 16-6 mean	69.04	134.99	28.68	55.56	1.46	0.03	3511.08	9.67	108.45	0.09	0.08	0.45	#NULL!
LL 17-1 mean	78.93	122.80	38.68	60.94	2.19	0.09	4391.11	10.78	113.75	0.13	0.14	0.61	#NULL!
LL 17-2 mean	72.37	92.76	29.41	47.80	2.38	0.10	3667.40	9.79	103.59	0.12	0.06	0.57	#NULL!
LL 17-3 mean	78.18	208.84	25.73	39.14	1.82	0.06	4033.26	12.04	106.53	0.11	0.06	0.46	#NULL!
LL 17-4 mean	79.63	204.11	28.32	27.78	1.88	0.06	3971.52	11.04	98.96	0.12	0.09	0.48	719.62
LL 17-5 mean	77.83	190.53	30.66	36.78	1.94	0.06	4594.02	11.33	111.59	0.12	0.08	0.54	930.17
LL 17-6 mean	73.14	89.30	27.87	46.30	2.66	0.11	3483.30	9.31	86.94	0.11	0.13	0.51	#NULL!
LL 18-1 mean	77.72	172.68	23.85	36.88	1.53	0.04	2951.27	9.12	82.14	0.11	0.07	0.49	607.61
LL 18-2 mean	78.34	174.41	24.47	46.04	1.56	0.04	2994.22	10.71	90.74	0.11	0.07	0.48	#NULL!
LL 18-3 mean	68.05	173.10	23.48	52.39	1.76	0.05	2865.55	10.70	104.44	0.10	0.06	0.42	715.82
LL 18-4 mean	79.95	180.12	28.77	42.24	1.81	0.05	3377.58	8.97	98.04	0.12	0.08	0.50	12163.52
LL 18-5 mean	77.95	185.76	28.48	34.38	1.70	0.05	3180.12	#NULL!	113.45	0.12	0.07	0.52	#NULL!
LL 18-6 mean	86.40	208.49	27.39	61.07	2.16	0.06	2976.15	11.17	94.77	0.11	0.08	0.44	#NULL!
LL 19-1 mean	#NULL!	162.42	#NULL!	52.48	2.24	0.10	5341.37	#NULL!	130.69	0.17	0.09	#NULL!	#NULL!
LL 19-2 mean	95.55	157.16	33.93	73.03	1.85	0.07	3970.25	10.37	103.62	0.13	0.08	0.65	10583.47

LL 20-1 mean	#NULL!	150.56	#NULL!	62.39	1.67	0.09	3690.08	#NULL!	114.90	0.15	#NULL!	#NULL!	#NULL!
LL 20-2 mean	#NULL!	172.28	#NULL!	39.30	1.90	0.11	4626.05	#NULL!	137.21	#NULL!	0.08	#NULL!	958.50
LL 2-1 mean	#NULL!	111.06	#NULL!	46.96	1.37	0.05	4491.33	9.98	97.60	0.16	0.09	#NULL!	14794.19
LL 21-1 mean	#NULL!	135.48	#NULL!	72.89	2.21	0.13	3646.40	10.77	107.22	0.14	0.10	#NULL!	#NULL!
LL 21-2 mean	#NULL!	170.47	#NULL!	43.77	1.68	0.09	3946.67	#NULL!	114.59	0.16	0.09	#NULL!	3052.42
LL 2-2 mean	#NULL!	89.83	#NULL!	53.20	1.57	0.06	4778.61	9.08	105.37	0.16	0.09	#NULL!	10007.80
LL 3-1 mean	82.74	52.54	37.14	39.47	0.97	0.04	3070.01	6.48	77.61	0.08	0.05	#NULL!	866.89
LL 3-2 mean	#NULL!	116.86	36.55	57.55	1.33	0.05	3179.52	7.50	81.04	0.11	0.06	#NULL!	6111.31
LL 4-1 mean	58.87	54.39	29.08	57.49	1.11	0.06	2498.51	8.14	84.15	0.06	0.08	0.48	1170.67
LL 4-2 mean	65.80	#NULL!	24.35	50.62	1.12	0.08	#NULL!	7.09	#NULL!	0.04	0.06	0.42	4767.59
LL 4-3 mean	72.10	#NULL!	22.48	#NULL!	1.72	#NULL!	#NULL!	8.59	#NULL!	0.04	0.07	0.42	6579.53
LL 4-4 mean	61.34	304.48	18.43	59.98	1.26	0.10	#NULL!	8.41	129.87	0.04	0.12	0.27	10061.45
LL 4-5 mean	67.19	#NULL!	20.42	51.70	1.05	0.08	#NULL!	7.84	#NULL!	#NULL!	0.07	0.34	9345.57
LL 4-6 mean	72.95	#NULL!	28.29	36.60	0.98	0.08	#NULL!	7.28	#NULL!	0.05	0.06	0.50	7852.80
LL 5-1 mean	89.98	202.75	35.65	44.95	0.93	0.08	10595.71	8.30	130.67	0.06	0.11	0.62	4119.93
LL 5-2 mean	66.10	346.09	25.56	#NULL!	1.48	0.15	#NULL!	10.57	#NULL!	0.05	0.07	0.48	1848.42
LL 6-1 mean	80.05	#NULL!	22.72	82.93	1.66	#NULL!	#NULL!	10.84	#NULL!	#NULL!	0.12	0.56	11283.86

LL 6-2 mean	77.50	#NULL!	16.28	90.09	1.88	#NULL!	#NULL!	8.58	123.35	#NULL!	#NULL!	0.33	5804.25
LL 6-3 mean	77.51	328.98	24.56	#NULL!	1.91	#NULL!	#NULL!	9.16	#NULL!	0.06	0.07	0.66	2280.26
LL 6-4 mean	82.16	371.56	21.14	#NULL!	1.60	#NULL!	#NULL!	8.08	#NULL!	0.05	0.15	0.67	1006.00
LL 6-5 mean	68.79	189.32	12.42	44.78	0.88	0.13	3899.00	7.23	63.71	0.06	0.09	0.28	#NULL!
LL 6-6 mean	71.12	121.27	24.18	41.33	#NULL!	0.10	2382.21	8.72	80.26	0.06	#NULL!	0.41	#NULL!
LL 7u-1 mean	82.23	345.06	18.32	35.98	0.60	0.11	7298.06	9.39	130.06	0.04	0.08	0.51	#NULL!
LL 7u-2 mean	61.31	87.01	24.73	85.52	2.24	0.09	2057.26	6.02	68.41	0.10	#NULL!	0.54	11102.23
LL 7u-3 mean	63.91	171.57	30.64	47.29	1.34	0.12	9420.61	6.36	120.50	0.05	0.09	0.55	#NULL!
LL 7u-4 mean	83.16	343.26	33.81	70.82	2.16	#NULL!	#NULL!	6.72	#NULL!	0.10	0.11	#NULL!	#NULL!
LL 7u-5 mean	#NULL!	311.08	#NULL!	76.45	2.54	#NULL!	#NULL!	11.99	#NULL!	#NULL!	#NULL!	#NULL!	#NULL!
LL 7u-6 mean	87.14	356.93	32.43	67.13	2.11	#NULL!	#NULL!	7.84	#NULL!	0.10	#NULL!	#NULL!	#NULL!
LL 8-1 mean	67.44	73.57	28.21	50.77	1.66	#NULL!	5619.15	7.77	101.54	0.04	0.09	0.50	669.99
LL 8-2 mean	80.24	136.80	35.92	40.79	1.23	0.12	9619.22	6.54	132.96	0.07	0.05	0.61	581.21
LL 8-3 mean	75.57	237.50	21.01	47.89	1.33	0.15	#NULL!	9.43	#NULL!	0.05	0.08	0.49	#NULL!
LL 8-4 mean	#NULL!	#NULL!	26.94	63.86	1.47	#NULL!	#NULL!	13.10	#NULL!	0.06	0.11	#NULL!	#NULL!
LL 8-5 mean	64.83	356.49	#NULL!	48.63	1.11	0.14	#NULL!	6.71	124.49	0.04	0.16	#NULL!	733.38
LL 8-6 mean	89.60	123.15	28.26	48.39	1.62	#NULL!	9941.78	8.97	140.11	0.06	0.08	0.55	#NULL!
LL 9-1 mean	65.13	224.00	31.70	64.49	1.72	0.09	6295.31	9.20	101.64	0.10	0.08	0.49	1315.24

LL 9-2 mean	67.15	254.54	24.16	55.29	1.75	0.10	7146.95	9.37	95.12	0.10	0.11	0.45	#NULL!
LL 9-3 mean	71.49	230.44	28.66	68.24	1.65	0.09	6564.17	7.40	102.84	0.10	0.09	0.48	923.58
LL 9-4 mean	68.44	129.26	30.06	72.94	1.94	0.09	5295.22	8.01	90.07	0.08	0.12	0.44	#NULL!
LL 9-5 mean	58.08	129.98	26.40	72.99	2.07	0.10	4496.18	6.20	90.79	0.08	0.09	0.42	#NULL!
LL 9-6 mean	64.01	213.71	26.13	47.68	1.81	0.07	6048.74	10.35	94.20	0.08	0.09	0.40	14848.88

Appendix K

Results of DFA of Niton Compositions of Artifacts and WD-XRF Compositions of Quarry Samples

Table K.1 DFA classification function coefficients for artifact compositions collected on the Niton and quarry sample compositions collected on the WD-XRF.

	Group		
	Landmark Gap Quarry	Long Tangle Lake Quarry	Artifacts
K2O	-1.775	.370	-.391
CaO	5.291	-.486	.047
MnO	30.922	62.394	17.508
FeO	3.377	.949	.400
Zn	-.102	-.016	-.011
Rb	.097	.028	.016
Zr	-.008	-.008	.032
(Constant)	-12.574	-6.358	-4.099

Table K.2 Predicted group membership of artifact compositions collected on the Niton and quarry sample compositions collected on the WD-XRF.

		Group	Predicted Group Membership			Total
			Landmark Gap Quarry	Long Tangle Lake Quarry	Unknown	
Original	Count	Landmark Gap Quarry	50	0	0	50
		Long Tangle Lake Quarry	0	51	6	57
		Unknown	12	34	456	502
	%	Landmark Gap Quarry	100.0	.0	.0	100.0
		Long Tangle Lake Quarry	.0	89.5	10.5	100.0
		Unknown	2.4	6.8	90.8	100.0
Cross-validated [b]	Count	Landmark Gap Quarry	50	0	0	50
		Long Tangle Lake Quarry	0	50	7	57
		Unknown	12	36	454	502
	%	Landmark Gap Quarry	100.0	.0	.0	100.0
		Long Tangle Lake Quarry	.0	87.7	12.3	100.0
		Unknown	2.4	7.2	90.4	100.0

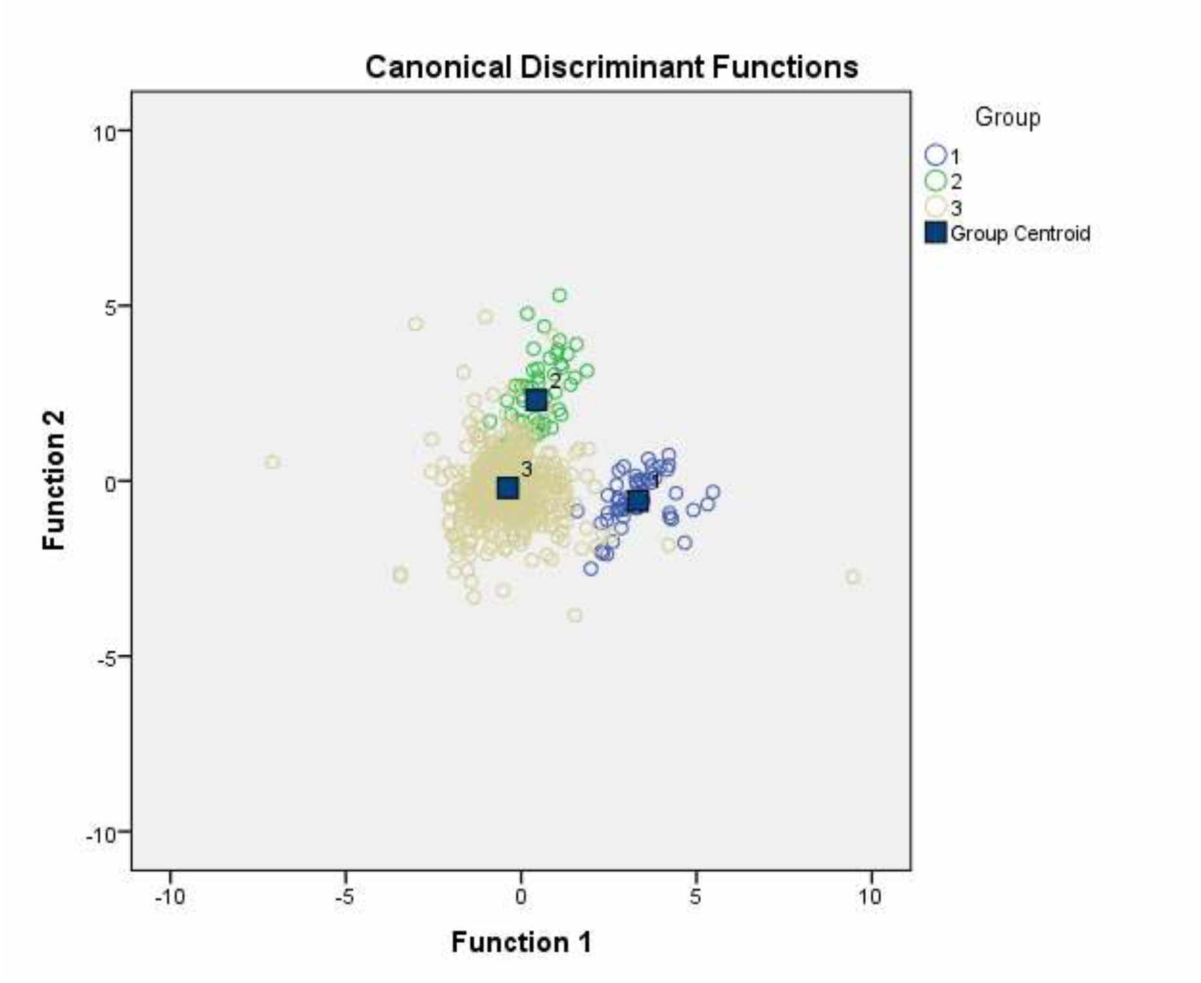

Figure K.1 Discriminant function plot of the quarry groups with compositions collected on the WD-XRF and artifact compositions collected on the Niton, where the Landmark Gap Quarry samples are Group 1, Long Tangle Lake Quarry samples are Group 2, and Group 3 is made up of artifacts.

Appendix L

DFA Statistics for Artifact Assignments

Table L.1 Descriptive statistics and equality of group means of Niton quarry group compositions and artifact assignments.

Quarry group		Mean	Std. Deviation	Valid N (listwise) Unweighted	Valid N (listwise) Weighted
Unknown (artifacts)	Zr	144.8	83.7	571.0	571.0
	Zn	47.1	44.0	571.0	571.0
	FeO	2.1	1.3	571.0	571.0
	MnO	0.1	0.0	571.0	571.0
	CaO	0.6	0.6	571.0	571.0
Landmark Gap Quarry	Zr	149.5	40.4	54.0	54.0
	Zn	36.0	6.2	54.0	54.0
	FeO	2.9	0.4	54.0	54.0
	MnO	0.0	0.0	54.0	54.0
	CaO	0.9	0.2	54.0	54.0
Long Tangle Lake Quarry	Zr	71.2	8.4	62.0	62.0
	Zn	53.3	12.7	62.0	62.0
	FeO	1.6	0.4	62.0	62.0
	MnO	0.1	0.0	62.0	62.0
	CaO	0.1	0.0	62.0	62.0
Total	Zr	138.6	80.0	687.0	687.0
	Zn	46.8	40.5	687.0	687.0
	FeO	2.1	1.3	687.0	687.0
	MnO	0.1	0.0	687.0	687.0
	CaO	0.6	0.6	687.0	687.0

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
Zr	0.929	26.0	2.0	684.0	0.0
Zn	0.992	2.8	2.0	684.0	0.1
FeO	0.952	17.1	2.0	684.0	0.0
MnO	0.985	5.3	2.0	684.0	0.0
CaO	0.907	34.9	2.0	684.0	0.0

Table L.2 DFA stepwise statistics of Niton quarry and artifact compositions.

Variables Entered/Removed[a,b,c,d]									
		Wilks' Lambda							
						Exact F			
Step	Entered	Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	CaO	0.9	1.0	2.0	684.0	34.886	2	684.000	0.000
2	Zn	0.9	2.0	2.0	684.0	23.722	4	1366.000	0.000
3	Zr	0.8	3.0	2.0	684.0	21.787	6	1364.000	0.000
4	FeO	0.8	4.0	2.0	684.0	19.608	8	1362.000	0.000
5	MnO	0.8	5.0	2.0	684.0	18.196	10	1360.000	0.000

Table L.3 DFA stepwise statistics of the Niton quarry and artifact compositions for variables in analysis.

Variables in the Analysis				
Step		Tolerance	F to Remove	Wilks' Lambda
1	CaO	1.0	34.9	
2	CaO	0.9	46.0	1.0
	Zn	0.9	12.9	0.9
3	CaO	0.7	21.4	0.9
	Zn	0.8	19.8	0.9
	Zr	0.6	17.0	0.9
4	CaO	0.6	10.0	0.8
	Zn	0.6	25.3	0.9
	Zr	0.6	17.0	0.8
	FeO	0.5	12.1	0.8
5	CaO	0.6	7.6	0.8
	Zn	0.6	15.2	0.8
	Zr	0.6	16.5	0.8
	FeO	0.4	18.9	0.8
	MnO	0.7	11.5	0.8

Table L.4 DFA stepwise statistics of the Niton quarry and artifact compositions for variables not in analysis.

Variables Not in the Analysis					
Step		Tolerance	Min. Tolerance	F to Enter	Wilks' Lambda
0	Zr	1.0	1.0	26.0	0.9
	Zn	1.0	1.0	2.8	1.0
	FeO	1.0	1.0	17.1	1.0
	MnO	1.0	1.0	5.3	1.0
	CaO	1.0	1.0	34.9	0.9
1	Zr	0.7	0.7	10.2	0.9
	Zn	0.9	0.9	12.9	0.9
	FeO	0.7	0.7	2.7	0.9
	MnO	1.0	1.0	12.1	0.9
2	Zr	0.6	0.6	17.0	0.8
	FeO	0.5	0.5	12.1	0.8
	MnO	0.8	0.7	4.4	0.9
3	FeO	0.5	0.5	12.1	0.8
	MnO	0.8	0.6	4.8	0.8
4	MnO	0.7	0.4	11.5	0.8

Table L.5 DFA group statistics of Niton compositions of quarry samples and artifacts.

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.227[a]	82.6	82.6	0.4
2	.048[a]	17.4	100.0	0.2
a. First 2 canonical discriminant functions were used in the analysis.				
Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	0.778	171.3	10.0	0.0
2	0.954	31.8	4.0	0.0

Table L.6 Standardized canonical discriminant function coefficients for groups of Niton compositions of quarry samples and artifacts.

Standardized Canonical Discriminant Function Coefficients		
	Function	
	1	2
Zr	0.350	1.1
Zn	-0.626	0.1
FeO	0.639	-1.0
MnO	-0.496	0.3
CaO	0.442	0.0